Equipment and Operational Modifications for Hopper Dredges to Reduce Impacts on Sea Turtles in the Southeastern USA

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Abstract: Hopper dredging projects along the southeastern USA potentially impact five species of threatened or endangered sea turtles. Incidental takes of sea turtles, both dead and alive, have been documented during hopper dredging activities since 1980 in coastal channels from the Texas-Mexico border through Pennsylvania For over two decades, the U.S Army Corps of Engineers (USACE) and the dredging industry have made a large investment to develop protocols, operational methods, and modify dredging equipment to reduce potential dredging impacts to sea turtles. These efforts have been very successful as evidenced by dramatic reductions in incidental takes in comparison to the increasing number of dredged channels monitored.

In the 1980's and early 1990's a combination of engineering and biological studies was done to develop the suite of protective tools currently available. This paper emphasizes the design, construction, testing and implementation of a rigid turtle deflector attached to the California style draghead. Laboratory tests with model turtles showed it to be very effective in deflecting the turtles. A prototype draghead tested with mock turtles made of lightweight air-entrained concrete, showed the deflector to be 95% effective in deflecting the model turtles. A subsequent full-scale field test during channel dredging with sea turtles present was successful in demonstrating dramatic reductions in sea turtle incidental takes. Since 1992, when a wide range of operational protocols including the rigid draghead were implemented, turtle takes per channel dredged have been reduced to extremely low levels.

The existing dredging window from December 1 through March 31 causes scheduling problems, reduces competition, and decreases safety for the dredge crew; therefore, the USACE and dredge industry are interested in expanding the existing dredging window. Developing new dredging alternatives and protection methods to further reduce turtle takes may provide justification for increasing the current dredging window. These options will be reviewed in 2004, and include additional modifications to the draghead, additional monitoring and training, and new contracting procedures.

Keywords: sea turtles, draghead design, deflectors, hopper dredge operations, contracting

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1 INTRODUCTION

The U.S. Army Corps of Engineers (USACE) has a mission to maintain navigation on federal navigation projects in the United States. Most navigation channels require regular dredging to maintain adequate channel depths. Trailing suction hopper dredges (referred to as hopper dredges from now on) are routinely used to maintain many deep draft channels (>10m deep). Unfortunately, the dredge's dragheads used to remove sediments from the bottom can entrain sea turtles resting in or on the bottom. Hopper dredging along the United States Eastern and Gulf of Mexico coasts potentially impacts five species of threatened or endangered sea turtles. The Endangered Species Act (ESA) of 1973 (US Fish and Wildlife Service, 2004) requires that threatened and endangered species be protected. To comply with ESA, the USACE must consider all alternatives and protective measures to safeguard threatened and endangered sea turtle species by minimizing or eliminating incidental takes of sea turtles during hopper dredging. Additional details on how the ESA applies to dredging where sea turtles are present can be found in Dickerson et al. (2004).

Incidental takes of sea turtles during hopper dredging have been documented since 1980 in 34 different coastal channels from the Texas-Mexico border through Pennsylvania. The need to maintain navigation with efficient and cost effective dredging on channels with sea turtles while reducing turtle takes to a low level has been a challenge for the USACE and industry. These challenges have been successfully met but continued improvements are desired. As a result, the USACE has initiated a new effort to further reduce turtle takes. This paper describes: 1) past efforts to reduce turtle takes, focusing on improvements in draghead design, 2) changes to dredge operations to reduce takes, and 3) the reasons behind that effort and current plans for draghead modifications and other operational and contractual measures to reduce takes.

1.1 History of Turtle Takes and Early Efforts to Reduce Takes

The primary incident that brought turtle deaths due to hopper dredging to national attention was the 1980 maintenance dredging of the entrance channel to Canaveral Harbor, Florida, when 71 sea turtles were taken (Rudloe, 1981). In response to this problem, a Sea Turtle Dredging Task Force was formed by USACE Jacksonville District. Included in the task force were representatives from the National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service, the Florida Department of Natural Resources, the U.S. Navy and the USACE. Recommendations from the task force and others outside this task force significantly reduced the number of documented turtle takes throughout the 1980s. During a National Sea Turtle/Dredging Workshop in 1988 (Dickerson and Nelson, 1990), experts examined the problems and potential solutions more closely. The task force and workshop attendees provided the foundation for additional dredging alternatives and modifications that ultimately lead to the USACE's creation of a Sea Turtle Research Program (STRP).

The STRP, which lasted from 1991-1993, examined a wide spectrum of issues including; relative-abundance investigations, behavioral studies, acoustic-detection investigations, bio-acoustic studies, acoustic-dispersal evaluations, dredging equipment development, and dredging equipment evaluation. For a detailed summary of the STRP, see U.S. Army Engineer Waterways Experiment Station (1997). Dickerson et al (2004) provides a concise summary of the STRP.

A primary means of reducing turtle takes, implemented as early as 1984, were deflectors attached to the front of the draghead. The chain deflector, shown in Fig. 1 (Banks and Alexander, 1994), was thought to reduce turtle takes, but was regularly damaged and required a considerable effort to maintain. A summary of the various chain deflector types deployed in the 1980's is presented in Dickerson et al. (2004).

Through the 1980s, a number of operational modifications to hopper dredging operations, in addition to the use of a deflector, were devised to reduce turtle takes. The modifications are summarized in a USACE 1990 document (Dickerson et al., 1990). The modifications included: 1) seasonal restrictions (or dredging windows) when dredging activities could occur (turtles are most prevalent during spring, summer and fall); 2) turning off the pumps when the dragheads are lifted and lowered (to prevent the draghead from entraining a turtle when it passes over it); 3) reducing vessel speed (provides the turtle an increased time to escape); 4) changing the type of draghead (eliminate the use of a scoop-like opening as found on the IHC type dragheads); 5) trawling to relocate turtles prior to dredging, and 6) improved monitoring to determine if turtles were taken. The impact of these changes was quite substantial as noted by Dickerson et al. (2004); significant reductions in turtle takes were evident by the mid 80's. These operational protocols have continued to evolve over the years, as the number of overall turtle takes per project has continued to decline. The decline is most evident from 1992 to present, when turtle deflectors on the draghead; relocation trawling and dredging windows were implemented (Dickerson et al., 2004). The current set of protocols required by the USACE Jacksonville District, which has the greatest number of channels impacted by sea turtles, can be found at http://www.saj.usace.army.mil/pd/turtle.htm.

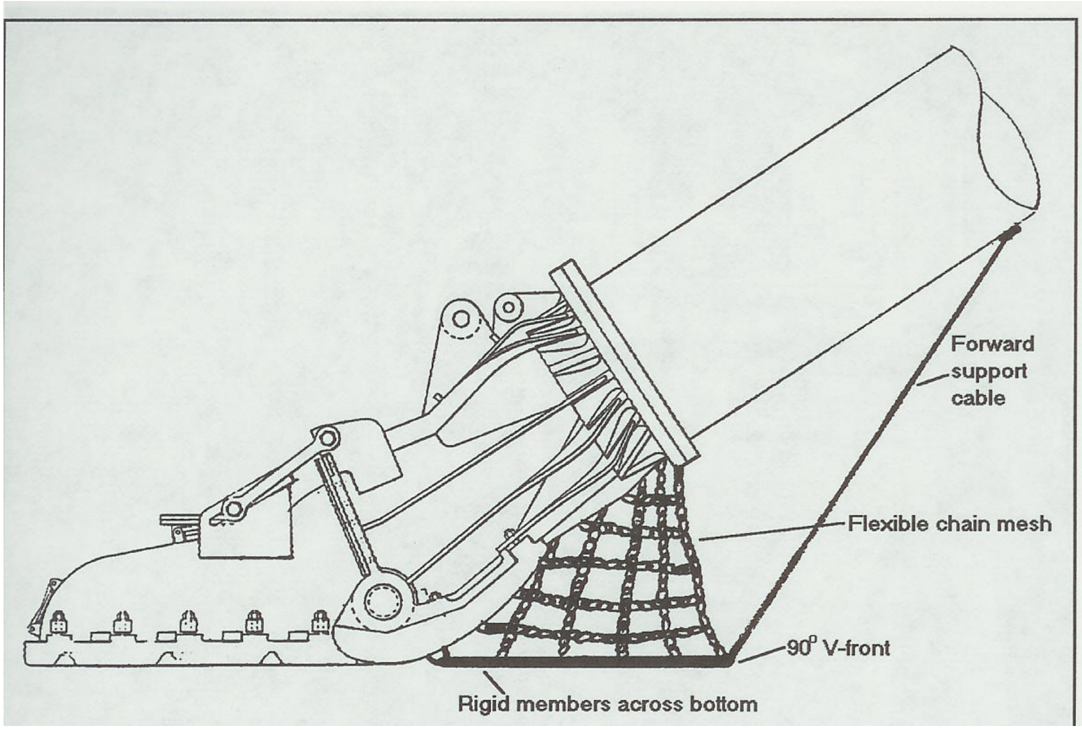

Fig. 1. Chain deflector mounted on a California draghead

The reductions in turtle takes over the past two decades are quite impressive. In fact, at the Atlantic Loggerhead Turtle Recovery Team Stakeholder Meeting in April 2003 meeting, the NMFS announced that it considers the USACE efforts to reduce turtle takes a model for other agencies and groups. However, the Corps has recently expressed renewed interest in further reducing turtle takes. This would also provide increased justification for the NMFS to extend the existing environmental window for dredging in sea turtle impacted channels. The present dredging window, based on water temperature, is December 1 through March 31 over most of the channels with turtles. This four-month window forces all dredging of the mid and lower east coast channels to occur during this time period. This greatly complicates scheduling of the US hopper dredge fleet (approximately 19 dredges including 1 USACE dredge active on the East Coast). This limited window also reduces competition and likely results in somewhat higher prices. An additional reason the USACE is interested in extending the sea turtle dredging window, is the desire to improve safety. Dredging during the winter means rougher seas and the corresponding increases in hazards and reduced efficiency. While the USACE has made very impressive reductions in turtle takes, the NMFS and other agencies continue to seek additional reductions in sea turtle takes. Finally, while the present deflecting draghead works well, improvements could further improve production over a range of depths and reduce clogging potential.

Renewed USACE interest in improving the draghead design began in 2002 with a joint proposal from Jacksonville District and the U.S. Army Engineer Research and Development Center's (ERDC) (formerly the U.S. Army Engineer Waterways Experiment Station) Coastal and Hydraulics Laboratory (CHL). Ultimately this lead to a wider discussion of options, for example improved training, improved monitoring, contractual options, etc., for reducing turtle takes for the reasons noted in the previous paragraph. A meeting of USACE and US dredging industry representatives was held in September 2003 in Atlanta, Georgia, to discuss the range of proposed options. Many of these options will be examined in more detail by a series of product delivery teams (PDTs) composed of USACE and Industry representative later in 2004.

The next section of the paper focuses on the original rigid deflecting draghead design and related operational requirements. The remainder of the paper discusses the full range of proposed options to further reduce turtle takes now under consideration by the USACE and the US dredging industry.

2 DEVELOPMENT OF THE RIDIG DEFLECTING DRAGHEAD

As noted above, various types of deflecting dragheads, based primarily on chains and plates were tried in the mid 80s to early 90s. While the combination of the draghead modifications and other operations were effective as noted above, the early chain and plate deflectors were very prone to damage. By the mid 80's only California style dragheads were being used on projects with turtles.

2.1 Rigid Draghead Deflector Development under the STRP

Before the STRP, research on improved designs of hopper dredge dragheads was done as part of the USACE sponsored Dredging Research Program (DRP) (Hales, 1995). This effort was focused on improving production and efficiency. One of the draghead shapes tested had a v-shaped leading edge that appeared to have potential as for deflecting turtles. Because the design also showed potential for good production, it was selected for further development under the STRP (Banks and Alexander, 1994).

A flume located at the U.S. Army Engineer Waterways Experiment Station (WES) was used for hydraulic model tests to refine draghead design. The model rigid deflector tests were conducted on level sand bottoms at 1/6 prototype scale, using neutrally buoyant foam discs as model turtles. Production values with the rigid deflector model were compared to standard California draghead model tests. The rigid deflector draghead model was completely effective in deflecting model turtles when the draghead stayed hard on the bottom and the leading edge angle of heel was oriented such that it pushed a shallow riffle ahead of the draghead. This sand “buffer” forms between the steel draghead and the turtle, pushing it out of the way. Because conventional dredging focuses on production only, the need to maintain hard bottom contact was new to the dredging industry. The decision was made to field test a full-scale prototype draghead.

Developing the contract specifications for the prototype draghead construction was a cooperative effort between the USACE Marine Design Center (MDC), Philadelphia and Jacksonville Districts, and WES. The MDC performed the design and the prototype draghead was constructed by NORSHIPCO, for the Philadelphia District’s hopper dredge *McFarland*. The prototype deflector is shown in Figs. 2 and 3. A major design constraint was the need to install the deflecting draghead using only ship-based equipment, imposing weight and geometric restrictions. To meet the weight limit, the heel pad of the existing California draghead was removed and replaced with a fixed visor. The rigid deflector draghead was designed as non –pivoting, i.e., fixed in relation to the angle of the dragarm. Thus, when dredging at the design water depth, 11 +/- 1 m, the draghead rides on the bottom at the proper angle for plowing. Note that the angle between the upper and lower portion of the dragarm is also critical. Ideally the pipes are not bent at the intermediate ball joint (Figure 4). At deeper and shallower depths, the draghead is less efficient. In deeper depths, less frequently encountered, there is greater potential for turtle takes. In shallower depths (i.e., shoaled areas that are most often encountered), additional material is pushed aside increasing wear.

Full-scale field tests were conducted using the USACE dredge *McFarland* at Fort Pierce, Florida, USA, in July 1993, on three draghead configurations: 1) a California-style draghead with no turtle deflector, 2) a California-style draghead with a V-shaped, flexible chain deflector, and 3) a California-style draghead with a V-shaped, rigid deflector. All three configurations were tested for their effectiveness in deflecting mock turtles and the production rate of dredged material. Field-testing consisted of dredging passes through a gridded pattern of model turtles and measuring both production and the number of model turtles deflected or damaged. This site had a relatively flat sandy bottom at a depth of 14.5 to 16 m, clear water (allowing video taped documentation), low bottom current velocities (to keep the turtles in place), and no protected mammals or fisheries resources. A critical item was the design of the model turtles. The model turtles were constructed of air entrained low-strength concrete, 500 mm in diameter, 150 mm thick at the center and tapering to 50 to 75 mm at the edge, with a submerged weight (18 to 22 Newtons) equal to that of a turtle.

Divers were used to deploy the model turtles in a grid pattern 73 m long and spaced 76 m apart. A total of five rows with 60 turtles each row were placed. The dredge then went through the grid pattern. Monitoring included inclinometers to measure the angle between upper and lower portions of the suction pipe**.** Video cameras were mounted to allow a view of the front and side of the draghead so that encounters with model turtles could be documented. For each run, production rate and the number of turtles “encountered” by the draghead were recorded.

On the test runs, the crew was instructed to follow normal dredging procedures. The California draghead with no deflecting mechanism entrained 14 (50%) of the 28 model turtles encountered while dredging. Another 14 were deflected, however, 9 were damaged (32%) when they were deflected. The California-style draghead fitted with a V-shaped, flexible chain deflector entrained four (12 %) of the 34 model turtles encountered and damaged one (3%) model turtle. The chain deflector did not create a prominent sand riffle in front of the draghead. For the draghead configuration with the rigid turtle deflector, only 2 (5%) of the 39 turtles encountered were entrained and none were damaged. It was noted that these two entrained model turtles were in a noticeable depression in the sediment. From a production standpoint, the rigid deflector showed a slight increase in production over the California draghead without any deflector. According to the dredge captain, steering with the v-shaped rigid deflector draghead was slightly easier than the conventional dragheads.

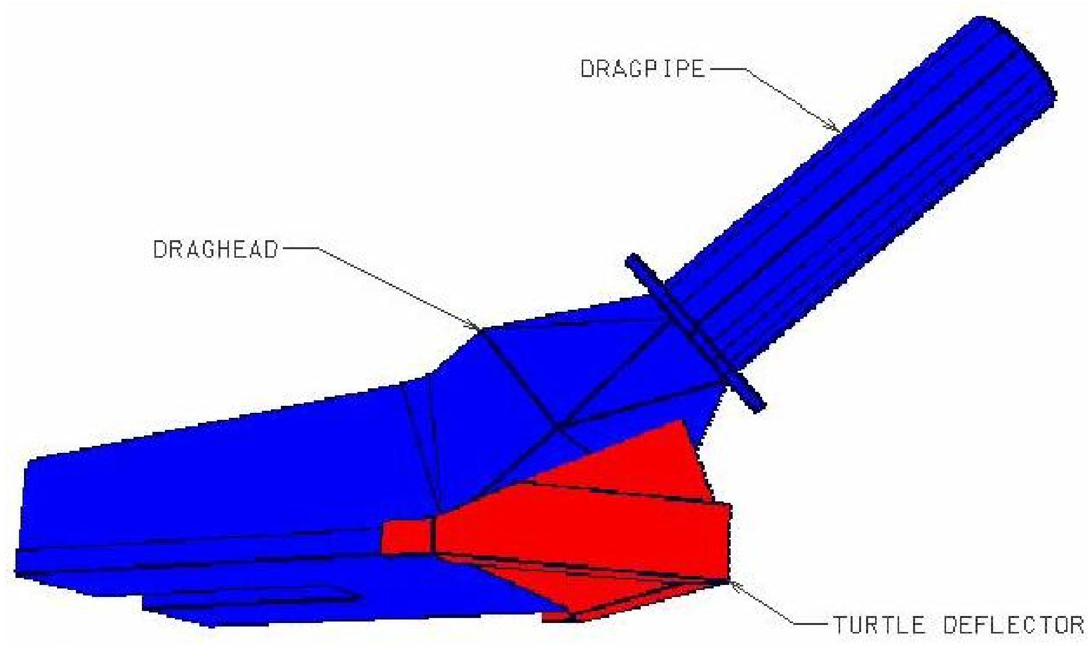

Fig. 2. Rigid deflector cartoon (source - http://www.saj.usace.army.mil/pd/turtle.htm)

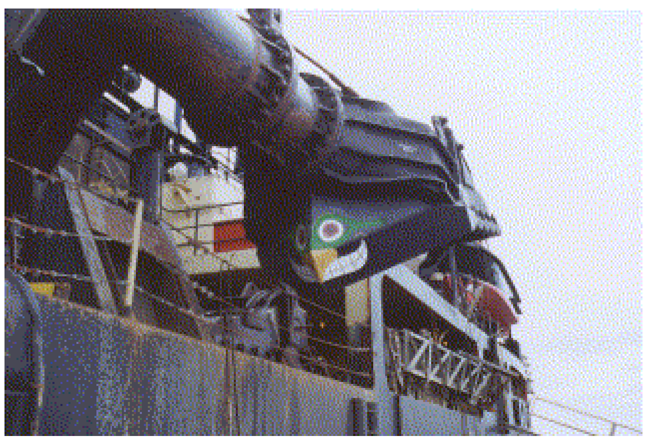

Fig. 3. Rigid deflector mounted on dredge *McFarland*

Both the model and the prototype tests showed the importance of keeping the draghead firmly in contact with the bottom such that the deflector portion extended roughly 150 mm into the bottom. This ensures that a sand wave is created in front of the draghead that allows the turtles to be deflected without causing injury. To achieve proper plowing, the "approach" angle of the draghead is critical. Fig. 5, acquired from Jacksonville District's sea turtle web page (http://www.saj.usace.army.mil/pd/turtle.htm), shows this concept.

Following the tests at Ft. Pierce the rigid deflecting draghead was tested at the Fernandina Harbor channel on the Florida/Georgia border during the winter of 1993/1994. During this testing, turtle abundance was low; therefore, this was not viewed as rigorous test of the deflecting aspect of the new draghead. The NMFS and the Jacksonville District initiated full-scale field-testing of the deflecting draghead at the Canaveral Harbor entrance channel where sea turtles were abundant to evaluate its dredging and deflecting efficiency.

2.3 Prototype Tests at Canaveral Harbor Entrance Channel

The Canaveral harbor channel, where many turtle are normally found, was selected as the site for these tests. During September 1994, a 13-day test was conducted. Prior to and during testing, a considerable amount of trawling was done to document the numbers and types of turtles present (Nelson and Shafer 1996). During the 15 days (69 hours) of dredging, while dredging 59,000 m^3 of material, only a single small green turtle was entrained by the dredge. This turtle was sufficiently small that it may have been

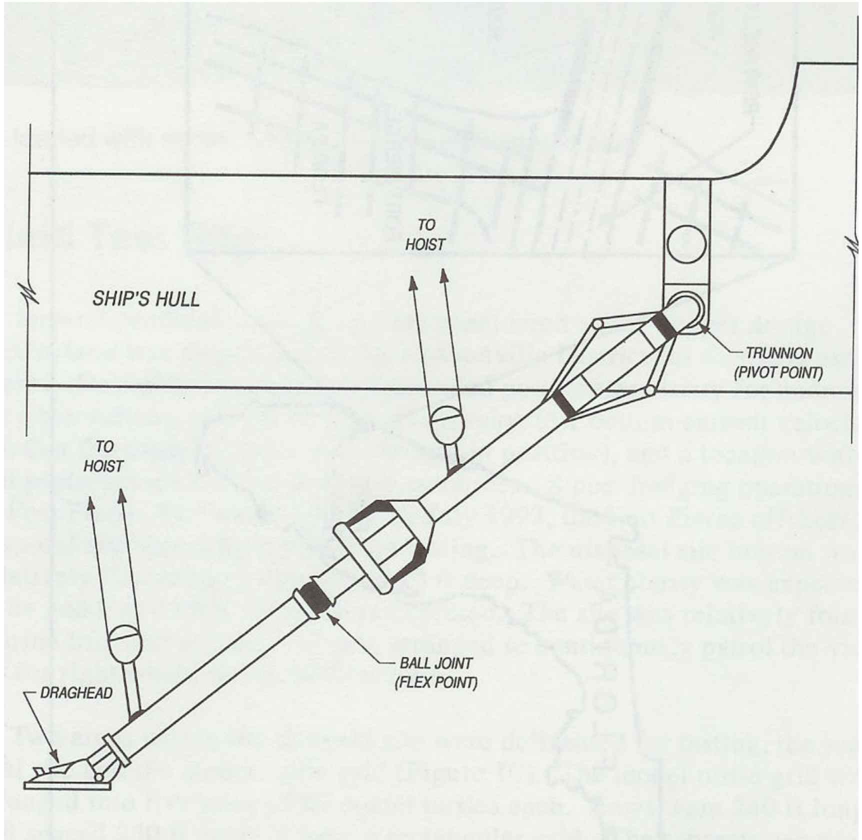

Fig. 4. Proper orientation of dragarms, upper and lower dragarm in a straight line (source Banks and Alexander 1995)

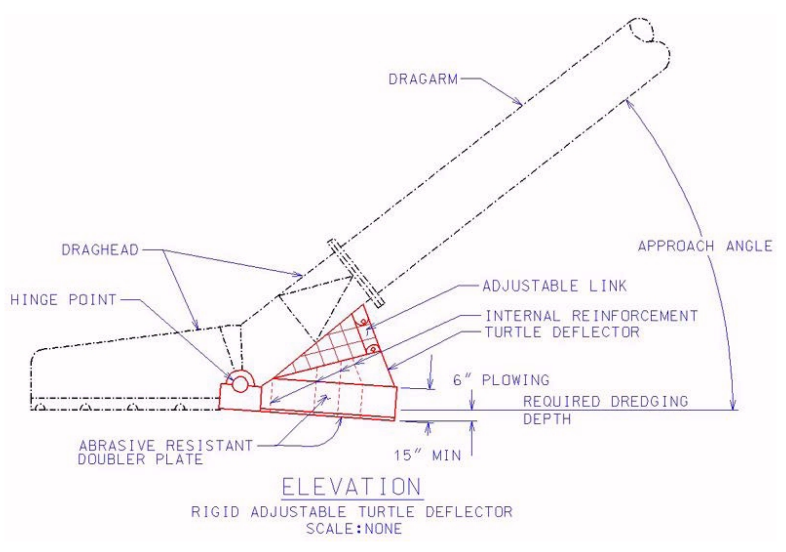

Fig. 5. Current draghead requirement sketch showing approach angle concept (source - http://www.saj.usace.army.mil/pd/turtle.htm)

entrained through the water intake opening on the upper side of the draghead. The turtle was recovered alive and later was released. Subsequently 10 cm grates were added to the upper water ports on the draghead. While the volume of sediment was low, the tests were thought to provide a reasonable level of confidence that the rigid deflector was effective in reducing turtle takes.

2.4 Industry Response to Corps Contract Requirements

Following the success of the rigid deflector tests at Ft. Pierce and the subsequent success during hopper dredging of the Canaveral Harbor Channel, the NMFS has, through their biological opinions, required the USACE and their contractors to use a rigid deflector during hopper dredging where turtles are present. Based on the Corps experience, the US dredging industry has developed rigid deflectors for their dredges.

The largest US Dredging Company, Great Lakes Dredge and Dock (GLDD), uses rigid deflectors on their hopper dredges, however, they do not use California dragheads. These dragheads have a single visor arrangement with the rigid turtle deflector attached at the same point (pins) as the visor. The GLDD dredge *Liberty Island* has automatic water flaps, however, the remainder of their hopper dredge fleet (5 dredges) do not have this feature.

2.5 Current Operating Protocols for Hopper Dredges

The operating protocols have continued to evolve over the years. For current operating protocols, specifications and guidance, see http://www.saj.usace.army.mil/pd/turtle.htm

3 RESULTS FROM USACE/INDUSTRY 2003 MEETING TO EXPLORE OPTIONS FOR FURTHER REDUCTIONS IN TURTLE TAKES

As noted in the introduction, while the rigid deflecting draghead and other operating protocols have resulted in very signficant drops in turtle takes, the need expand the dredging window and other considerations led ultimately to a USACE/Industry meeting in September 2003 to examine a range of options. This section describes the options now under consideration.

3.1 Improving Draghead Design – Adjustable Deflector

During dredging at depths outside the limited design range of the rigid deflecting draghead (approximately 10 to 12 m), production is significantly reduced. When dredging must accommodate rapid shifts in elevation, e.g., when encountering major shoals, the inability of the draghead to pivot and remain in full contact with the substrate reduces efficiency and increases the likelihood of turtle entrainment. A potential solution to this problem would be to update the present rigid sea-turtle deflector configurations to one in which an air chamber, spring-based forward pin support, or other means would allow the heel to pivot, requiring fewer dredge-location calibrations than are presently required.

Several hopper dredges have been constructed in the last five years and the dredging industry often performs scheduled major rebuild/repair jobs on many of the hopper dredges used on USACE projects with turtles each year. If implemented, this updated technology could possibly be included in scheduled major repair operations by the dredging fleets, thereby reducing implementation costs. The new system should be more effective at keeping the leading edge of the existing deflectors in constant contact with the bottom under all conditions. Recent developments in adjusting visors used on the NATCO Dredge *Liberty Island* and on a second generation pivoting visor designed for the Corps Dredge *McFarland* would be considered in the design. An assessment of future beach nourishment project borrow area depth ranges should be completed to determine if operating depths greater than 17 m should be considered in the design criteria.

An adjustable (pivoting) visor containing a rigid deflector was designed and constructed by the Marine Design Center for the USACE hopper dredge *McFarland* (Figure 6) in 1999. The weight and complexity of the adjustable visor is such that installation cannot be carried out aboard ship, a major drawback. Another drawback is that when dredging in rocky bottoms, some rocks may be trapped between the V-shaped forward moving part of the visor and the fixed internal part bolted in place of the heel pad. Lessons learned from this effort should be valuable in a more general redesign effort.

3.2 Improving Draghead Design: Automated Addition of Mixing Water

Another problem with USACE and Industry dragheads when used on projects with turtles is the potential for plugging the suction line when dredging sediments that can be removed in high concentrations (primarily mud bottom). The normal response of the dragtender in these situations is to lift the draghead off the bottom to increase the amount of water being entrained. However, this significantly increases the chance of entraining a turtle. The solution proposed is to have a system that automatically provides mixing water from another point on the draghead, for example pipes that stick up above the draghead. This arrangement has been tried on an industry dredge when dredging in areas with fluid mud. A concern with such a system would be if the added complexity negates some of the potential benefits. However, in the September 2003 meeting, industry representative were reasonably confident a workable system could be developed if needed and required. It is likely that a performance-based specification would ultimately be developed.

3.3 Improving Draghead Design: Redirection of Flow

The most radical of the proposed draghead designs is a system that would automatically redirect a large percentage of the flow away from bottom of the draghead to an alternative opening if the draghead lost contact with the bottom. This concept reduces the chance that an operator error would cause a turtle take. This is similar to the “Hoffer” valve concept on cutter-suction dredges. However, this radical concept may not be practical because the size of the opening would have to be quite large to intercept a significantly large portion of the flow. It would likely require a completely redesigned and more complicated draghead that also included a bottom contact sensor. During the September 2003 meeting, this concept generated a good deal of skepticism.

Figure 6. Articulated deflector draghead on the *McFarland*

3.4 Contractual Options to Reduce Takes

Although the historical records have not been thoroughly analyzed, anecdotal and preliminary observations indicate that more turtle takes typically occur during the latter few weeks of a dredging project. It has been suggested that the dredging activity stirs up food supplies and creates pockets and trenches in the sediment for sea turtles to retreat. These may even result in attracting or concentrating turtles into the area of dredging activity. Also, the pockets and trenches created make it more difficult to keep the draghead on the bottom. These trenches are due in part to the requirement to plow by forcing the draghead six inches into the bottom to create a sand wave in front of the draghead as described earlier. Because of this, it would be advisable to reduce dredging requirements in the clean-up phase however possible. Some potential changes to contractual requirements that might reduce the length of time the dredge is actually operating during the final cleanup phase include: a) increasing over-depth to at least 0.6 and in some cases 0.9 m; b) reducing depth tolerance from the channel toe to the ¼ point of the channel; c) allow the actual depth after dredging depth to be up to 0.3 m higher than the specified depth at the channel toe, and d) a consideration to having a different bid item for clean-up dredging reflecting the lower production rates achieved and providing additional incentives to be more careful.

Increasing the over-depth, the depth below the required dredging depth for which the contractor is paid, from 0.3 to 0.6 or 0.9 m would reduce the number of ridges remaining after the initial dredging effort, therefore reducing the amount of clean-up dredging required. Similarly, reducing the depth tolerance on the outer quarters of the channel, i.e., allowing portions to be up to 0.3 m above the targeted depth would reduce the amount of clean-up dredging required. Achieving the targeted depth in the channel immediately adjacent to the channel toe, where the channel side-slope meets the flat bottom, is most difficult due to material sloughing off the channel side-slope. Therefore, another option to reduce clean-up dredging is to allow the area immediately adjacent to the channel toe to be up to a 0.3 m above the target. The final option discussed above, provides a separate bid item for clean-up dredging. Because small volumes in relatively small areas are removed during clean-up dredging, the dredging efficiency and hence the production rate is low. In a contract with a single unit price for dredging, the contractor is losing money when doing clean-up dredging and hence may not be as slow and careful during this phase of the operation. Providing for a separate (higher priced) bid item during clean-up dredging should encourage more careful operation and hence reduce the likelihood of taking a turtle.

Other contracting options were discussed during the September 2003 meeting and have been considered in the past. The feasibility of implementing these options may be considered. These options included: incentives for not taking turtles, penalties for taking turtles, and allowing the inspector or captain to cease dredging when conditions are likely to cause the draghead not to remain in contact with the bottom. This condition can occur when winds and currents combine such that the dredge is forced to crab up the channel. Under these conditions, the dragarm on the up-current side can be forced under the dredge. When this occurs, the operator can be forced to lift the dragarm to avoid damaging it, increasing the potential for entraining turtles. Under consideration are decisions on when to allow the dredging contractor to dredge with only the downstream draghead and including a bid item for that. Also under discussion is a decision to halt dredging during severe waves that also increase the likelihood that the draghead may loose contact with the bottom when the swell compensator is unable to keep up with the vessel motion. In these cases the decision to halt dredging temporarily and the resulting loss of production must be balanced with the potential to reduce turtle takes. From a larger perspective, the potential for these actions to persuade the NMFS to increase the turtle dredging window and the benefits associated with that must be factored into the decisions.

3.5 Non-hopper dredge options for clean-up that may reduce turtle takes

Alternatives to hopper dredge use during the clean-up phase are also under consideration. One option is use of a water injection dredge (WID) (Clausner, 1993) (Fig 7.), essentially, a pump mounted on a barge that forces water under pressure through a large pipe with downward directed holes. When working, the WID rests the pipe on the bed, and moves back and forth directing high volume, low-pressure water into the sediments, causing them to fluidize and flow as a density current to an adjacent lower area. The low speed of the WID, typically 0.5 m /sec and the fact that it has no moving parts, would likely pose a low level threat to turtles. However, the effectiveness of the WID to perform this type of dredging is untested.

A non-hopper dredge option that has been tested for clean-up dredging is a bed leveler, also known as a drag beam or plough, Fig. 8. A bed leveler is an iron beam, old spud, or engineered plough that is lowered to the seabed and dragged across the bottom to level out high spots. A typical bed-leveler length may vary from 9 to 16 m, and weigh anywhere from 25 to 50 tonnes. The bed-leveler is suspended from a work-barge with an A-frame and winches. The barge is pushed or pulled by a tug. It has been used on a number of projects following hopper dredging to knock down high spots. While bed levelers are typically dragged at relatively low speeds, the size and shape do offer some potential, thought to be low, to harm turtles.

It is possible that some studies to examine more fully the potential for WID or bed-levelers to harm turtles may be required. Until that has occurred, it is virtually impossible to determine if these devices are safer than hopper dredges from a turtle perspective.

3.6 Communication and Documentation

Improved documentation of dredging activities concerning turtle takes should increase awareness and communications between the USACE, dredge companies, regulatory agencies, and environmental groups. A wide range of options has been proposed to increase communications and improve documentation between the USACE, Industry, and NMFS. Some of those options include:

a) ERDC staff working more closely with Districts to improve data collection during dredging, in post-dredging project summaries, and in archived post project files.
b) ERDC, Jacksonville District, and industry cooperatively develop training resources to more effectively train dragtenders to correctly operate the draghead/deflector equipment.
c) Improved monitoring of dredges to determine if they are being operated according to contract specifications. The Silent Inspector (SI) (Rosati and Prickett, 2001), a computer based system for monitoring contract dredging, has seen increasing use on USACE hopper dredging contracts in recent years. A demonstration of SI on a dredging contract where turtle takes are an issue is planned. It should be noted that the SI might also be used as an improved means to archive and analyze turtle take data.
d) Understanding when, where, and at what stage in a project turtles were entrained, as well as the entrainment rate of turtles (i.e., per kilometer of channel dredged, cubic meter of material dredged, etc.), provides a powerful tool for working with regulatory agencies to make informed management decisions. Archiving and analyzing the past and future sea turtle entrainment records will help to provide this information. ERDC is presently constructing an internet-based database to archive the dredging and sea turtle incidental take records for long-term continuity and evaluation of these data. An initial start is the historical data recently analyzed and reported in Dickerson et al. 2004.

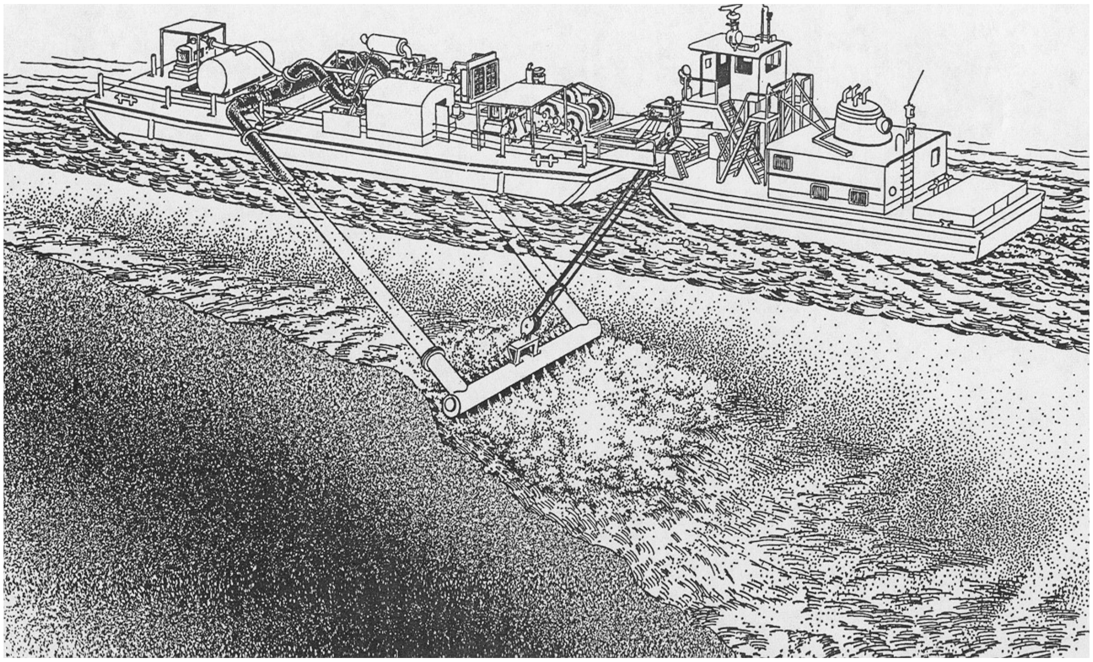

Fig. 7. Water Injection Dredge

Fig. 8. Bed-leveler (source Great Lakes Dredge and Dock)

4 SUMMARY

Reducing turtle takes to acceptable levels while maintaining navigation in the Southeastern United States has been successfully done by a combined effort of the USACE and US dredging industry. Starting in the early 1980s and culminating in a large research program in the early 1990's, a combination of biological knowledge, engineering solutions, and operating protocols have dramatically reduced turtle takes by hopper dredges. A key component was the development of a rigid deflector mounted to the hopper dredge draghead. However, a combination of the desire to further reduce costs, increase competition, and improve safety has lead to an initiative to expand the existing environmental window in which hopper dredging is allowed. A recent USACE/Industry meeting has identified a range of options with the potential to further reduce turtle takes in the hope this will be sufficient to expand the dredging window.

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