MARCH 2022
NEW YORK STATE DEPARTMENT OF STATE

MARITIME TECHNICAL WORKING GROUP ANCHOR STRIKE STUDY

SUMMARY REPORT

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Version History

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2.0	03/03/2022	Final Report
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Abbreviations and Acronyms

BOEM	Bureau of Ocean Energy Management
CL&P	Connecticut Light and Power Company
DOS	New York State Department of State
DNVGL	Det Norske Veritas Germanischer Lloyd
DWT	Deadweight tonnage
kV	kilovolt
LIPA	Long Island Power Authority
LOA	length overall
MARS	Maritime Alerting and Reporting Scheme
M-TWG	Maritime Technical Working Group
MW	megawatt
NCEL	Naval Civil Engineering Laboratory
NOAA	National Oceanic and Atmospheric Administration
NYPA	New York Power Authority
NYS	New York State
NYSERDA	New York State Energy Research and Development Authority
OREI	Offshore Renewable Energy Installation
PANYNJ	Port Authority of New York and New Jersey
PSEG	Public Service Enterprise Group Inc.
SHPA	Sandy Hook Pilots Association
TEU	twenty-foot equivalent unit (i.e. in reference to a shipping container)
USACE	U.S. Army Corps of Engineers
USCG	U.S. Coast Guard
USD	U.S. dollars

USDOT PHMSA	U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration
USN	U.S. Navy

EXECUTIVE SUMMARY

New York State is a national leader in addressing climate change and advancing responsible offshore wind development. Recognizing that New York State has a substantial potential for offshore wind production, the Climate Leadership and Climate Protection Act (NYS Climate Act) mandates 9,000 megawatts (MW) of offshore wind energy generating capacity by 2035. At the same time, New York Harbor is one of the busiest waterways in the world. The inter-state regional economy relies on the maritime industry to provide safe, reliable transportation of people and goods into and out of New York State; therefore, it is critical that offshore wind and traditional maritime industries co-exist and work collaboratively to reap the co-benefits of a robust offshore wind industry (e.g. workforce opportunities, supply chain, infrastructure upgrades).

The Maritime Technical Working Group (M-TWG), led by the New York State Department of State (DOS) and supported by NYSERDA, is one of four Technical Working Groups established by New York State to cultivate a representative cross-section of stakeholder interests and expertise to ensure that the State's offshore wind program development and initiatives are informed by and founded upon constructive dialogue with stakeholders. The M-TWG is an unofficial, non-decision-making advisory entity which addresses this important outreach to the New York State and regional stakeholders with maritime responsibilities and interests impacting New York State's offshore wind mandate.

The work of the M-TWG is specifically focused on issues relating to offshore wind and commercial navigation. One aspect of offshore wind development that has raised concerns among the maritime industry representatives is the ongoing need for vessels to anchor, combined with the addition of new submarine cables which will be installed in the seabed of New York Harbor and the New York Bight. Submarine cables are required to transmit the power generated by offshore wind turbines to offshore collection points (offshore substations) and then to shore. Due to the necessity of connecting the offshore infrastructure with onshore electrical demand, cables to/from an offshore renewable energy installation (OREI) are occasionally required to cross a navigation channel, traffic lane, fairways, etc. It is generally recommended that the frequency and lengths of these crossings be limited, but where they are necessary, and where vessels transit outside of established traffic lanes, there is a risk that a dropped anchor may impact or damage a cable. There is a corresponding risk that an electrical cable can foul a vessel's anchor. If an anchor is fouled or damaged to a degree that it cannot function as intended, especially in a loss of propulsion or steering emergency, the vessel, and consequently its crew and cargo, could be endangered.

This is an informational report that presents the results of two fact-finding activities completed for the M-TWG, specifically:

- Compile a database of known or suspected commercial shipping anchor strike occurrences along the U.S. East Coast; and

- Review existing methodologies and estimate the range of anchor penetration depths for the vessels that commonly operate in the New York Bight and New York Harbor, including next generation vessels capable of fitting below New York region bridges.
  - The anchor penetration task does not evaluate the risk of an anchor strike, nor does it make any judgements on the probabilities of an anchor deployment, an incident occurring, or external factors that could influence vessel behavior in emergency situations (e.g., water depth, bathymetric profile, presence of obstructions).
  - Analyses of cable burial risks and specific burial depth recommendations are beyond the study's scope.

The list of suspected commercial shipping anchor strikes was compiled through outreach to infrastructure owners and operators, searches for media reports, and review of incident reports filed with organizations such as the U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration (USDOT PHMSA), Maritime Alerting and Reporting Scheme (MARS), the United States Coast Guard (USCG) and the New York State Department of Public Service. In total, a list of 19 suspected anchor strike incidents along the east coast of the United States was compiled, with the event dates spanning from 1969 through 2021. Four of these incidents were selected for more in-depth research and are presented as case studies. To the extent possible, the case studies selected represent a variety of geographically relevant locations and submarine infrastructure, though the limited depth of the publicly available information also dictated which incidents could be developed into case studies.

Methodologies for estimating anchor penetration depth are broken into two distinct categories: the dropped anchor scenario and dragged anchor scenario. In each scenario, three types of stockless anchors were considered, with their masses and contact area dimensions being key inputs.

In the dropped anchor scenario, the anchor falls vertically, impacts the seabed, and penetrates to a depth that it could potentially make a direct hit on the submarine cable. This scenario was evaluated for four surficial sediment types that could be found in the New York Bight and New York Harbor: silty/sandy clay, sand, gravelly sand, and gravel. The penetration depth was determined by equating the kinetic energy of the falling anchor with the energy absorption of the seabed material (based on bearing capacity across the contact area) and solving for the depth at which the anchor's vertical movement is brought to a halt. For the largest (mass) anchor that is expected to be carried onboard a vessel operating in the New York Bight, the penetration depth of a dropped anchor scenario was estimated to be up to 2.5m (8.2 ft) in silty/sandy clay and 2.1m (6.9 ft) in sand.

In the dragged anchor scenario, the anchor is released by a moving vessel and it digs into the seabed as it is dragged. Instead of an analytical calculation method like the one employed in the dropped anchor scenario, the accepted method of estimating drag anchor penetration is through use of empirical data and relationships. One widely used empirical method relates the anchor fluke length to penetration depth for two categories of sediment: 1) soft silts and clays, and 2) sands and stiff clays. For the range of anchor sizes expected to be carried onboard vessels operating in the study area, the largest fluke length yielded an estimated maximum drag anchor penetration of 8.4m (27.6 ft) in soft silt/clay and 2.8m (9.2 ft) in sand/stiff clay. A high-level summary of results is presented in Table 1-1. Note that Table 1-1 presents data for three example vessel lengths (LOA) to provide context for the results in a more approachable format than tabulating penetration vs. anchor size. These chosen LOAs correspond roughly to typical anchor sizes carried onboard vessels of these lengths.

Table 1-1– High-level summary of estimated dropped and dragged anchor penetration depths in the two most common sediment types in the study area for various vessel lengths.

	Sediment Type	**200m (~650 ft) LOA**	**300m (~980 ft) LOA**	**400m (~1300 ft) LOA**
Dropped Anchor Penetration	Silty/Sandy Clay	0.3m – 1.6m	0.7m – 2.4m	0.9m – 2.5m
	Sand	0.5m – 1.5m	0.7m – 2.0m	0.9m – 2.0m
Dragged Anchor Penetration	Soft Silts & Clays	3.0m – 7.3m	4.3m – 8.4m	5.0m – 9.2m
	Sand & Stiff Clays	1.0m – 2.7m	1.4m – 2.8m	1.7m – 2.9m
Note: Contains aggregated results of methods described herein with consideration of generalized sediment types, common anchor equipment and vessels anticipated and commonly occurring in New York Harbor and the New York Bight.				

1 Introduction and Background

New York State has adopted the Climate Leadership and Climate Protection Act (NYS Climate Act), which mandates that at least 70% of New York's electricity come from renewable energy sources such as wind and solar by 2030, and that the state's electrical system is 100% carbon neutral by 2040. Recognizing that New York State has a substantial potential for offshore wind production, the NYS Climate Act specifically confirms a mandate of 9,000 megawatts (MW) by 2035 for the State's offshore wind program.

1.1 M-TWG

To facilitate realization of the offshore wind mandate, New York State founded four Technical Working Groups (TWGs) to specifically support engagement with stakeholders from each of the Fishing, Environment, Jobs and Supply Chain, and Maritime communities. The TWGs are each responsible for cultivating a representative cross-section of stakeholder interests and expertise to ensure that the State's offshore wind program development and initiatives are informed by and founded upon constructive dialogue with stakeholders.

The offshore wind Maritime Technical Working Group (M-TWG), led by the New York State Department of State (DOS) and supported by NYSERDA, is an unofficial, non-decision-making advisory entity which fulfills this role for New York State and regional stakeholders with maritime responsibilities and interests impacting New York State's offshore wind mandate. Serving as a forum to provide input and inform New York via interaction with DOS, the M-TWG seeks to identify and understand maritime and commercial navigation concerns, especially as these issues relate to construction and operation of offshore renewable energy installations (OREIs).

The members of the M-TWG were invited by DOS to reflect diverse viewpoints from key areas of knowledge related to maritime issues in the New York Bight and include a range of Federal and State Agency, maritime industry, and offshore wind industry stakeholders.

1.2 Objective & Scope

The work of the M-TWG is specifically focused on issues relating to commercial navigation. Issues relating to other waterway uses, such as commercial and recreational fishing, recreational boating, and other waterway uses that could interact with submarine cables are beyond the scope of the M-TWG and therefore specifically excluded from this study. BTMI Engineering, P.C. (COWI) was retained on behalf of DOS by NYSERDA to provide technical support to the M-TWG. The scope of this support task consisted of two primary activities:

- Compile research of known or suspected anchor strike occurrences along the U.S. East Coast on existing submarine infrastructure, such as cables or pipelines, and report as follows:
  - Compile a tabulated database of available details of the anchor strikes including information such as asset name/type/year commissioned, water depth, installation

method, burial depth, sediment type, date and location of incident, vessel type/size/anchor type, extent of damage, and outcome of any claims/litigation where available

  - Provide accompanying narrative summaries of case studies of four (4) specific anchor strike incidents

- Review existing methodologies and estimate the range of anchor penetration depths for the vessels that commonly operate in the New York Bight and New York Harbor, including next generation vessels capable of fitting below New York region bridges. The intent of this task was not to replicate or duplicate previous studies (e.g. Ref. [1] and Ref. [2]), but rather to leverage their work in order to focus the range of anchor penetration estimates for the vessels and conditions most likely to be encountered in NY Bight and NY Harbor.

  - Research existing methods of calculating anchor penetration depth for both dropped and dragged anchor scenarios.

  - Consolidate information on how vessel type, anchor type, and sediment types influence anchor penetration depths.

  - Calculate anchor penetration depths based on researched methods and create a matrix showing penetration depths for various vessel/anchor type and soil type combinations.

  - This task does not evaluate risk of an anchor strike or make any judgment on the probabilities of an anchor deployment, an incident occurring, or external factors that could influence vessel behavior in an emergency situation, such as water depth, bathymetric profile, presences of obstacles, etc. Analyses of cable burial risks and specific burial depth recommendations are beyond the study's scope.

1.3 Submarine Cables

Submarine cables are required to transmit the power generated by offshore wind turbines to each other, then an offshore collection point, and to shore. A comprehensive overview of offshore wind submarine cabling can be found in the Ref. [3] report prepared for the Fisheries Technical Working Group. In a typical commercial scale OREI, a string of five (5) to ten (10) wind turbines are connected to each other. Multiple strings of turbines are collected at an offshore electrical platform. From the electrical platform, one (1) or more export cables transmit the power to an onshore interconnection point.

Due to the necessity of connecting the offshore infrastructure with onshore electrical demand, cables to/from an OREI are occasionally required to cross a navigation channel, traffic lane etc. It is generally recommended that the frequency and lengths of these crossings are limited, but where they are necessary, and where vessels transit outside of established traffic lanes, there is a risk that a dropped anchor may impact or damage a cable. There is a corresponding risk that an electrical cable can foul a vessel's anchor. The risk will depend on the design, burial, and protection of the cable.

There are various ways of protecting transmission cables and significant experience to leverage from the domestic offshore pipeline industry and European offshore wind industry. The main method is to bury the cable wherever possible, though that depth is limited by heat dissipation requirements and the need to balance the cost of deeper burial with the benefit that added protection provides.

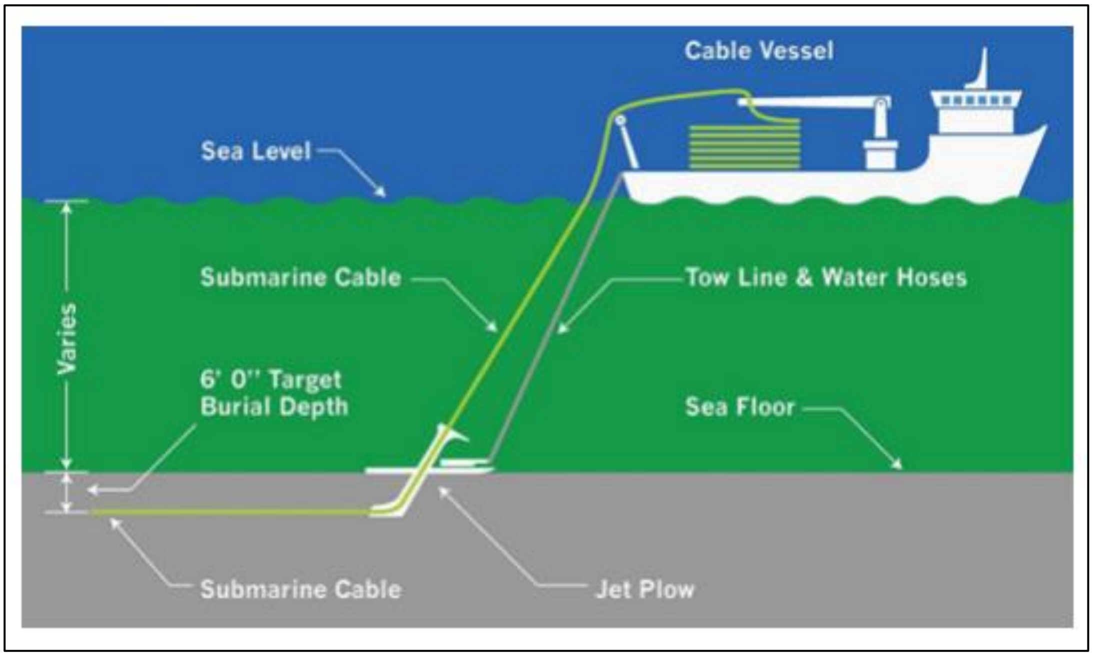

Figure 1-1 – Cable burial schematic (Ref. [4])

1.4 Anchors

Guidance and requirements that inform the selection of anchoring equipment are typically based on ordinary "stockless" anchors (Ref. [5]). Feedback received from the Sandy Hook Pilots Association (SHPA) indicates that stockless anchors are the typical anchor used on large commercial vessels. Therefore, this study uses input data (e.g., mass, fluke lengths, empirical correlations) for stockless type anchors in the estimates of anchor penetration depth of Section 3. The typical configuration of a stockless anchor is shown in Figure 1-2.

"Stockless" refers to the absence of the cross piece that positions the fluke so that it digs into the seabed. Stockless anchors were patented in the early 19th century and became popular, and remain so, because they are easier to handle and stow than stock anchors. The crown and fluke are cast as one piece and are able to pivot on the shank (Ref. [6]). This enables adjustment of the fluke angle (angle between the fluke and shank) for varying seabed conditions, which greatly influences its depth of penetration, and therefore holding capacity. Typically, larger fluke angles (~50°) are used for soft sediments like soft clay and silt, and smaller angles (~32°) are appropriate for harder seabed conditions like hard clay and sand (Ref. [7]).

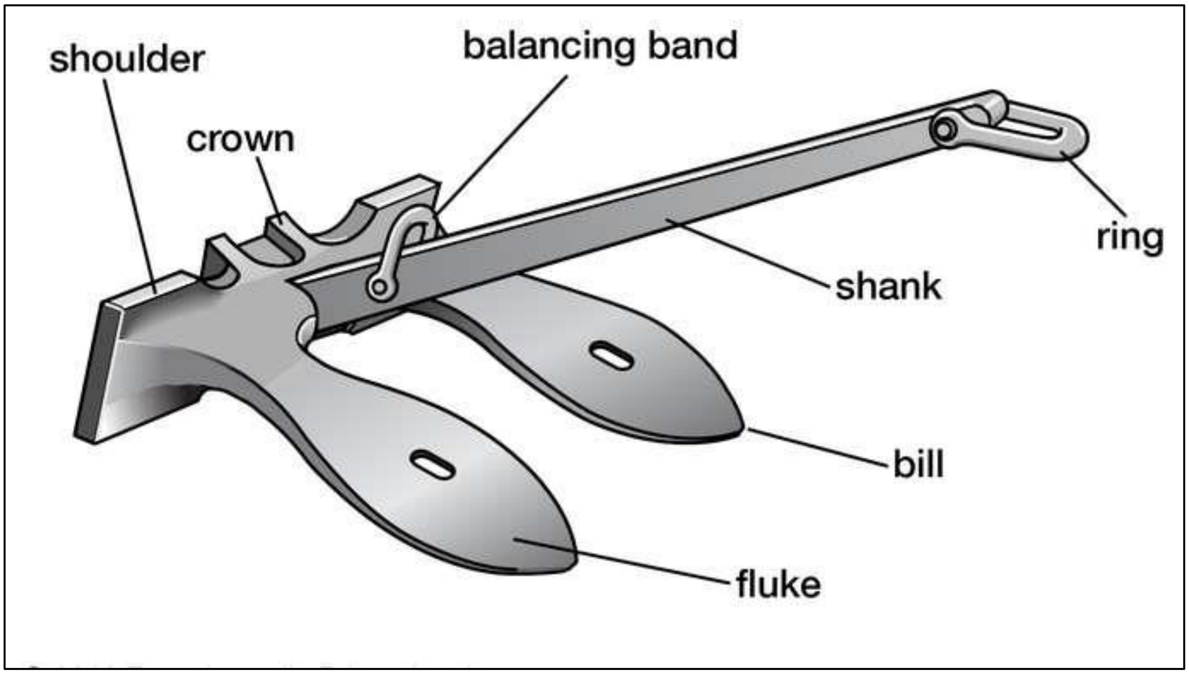

Figure 1-2 - Diagram of a stockless anchor (Ref. [6])

2 Vessel Anchor Strikes on Submarine Infrastructure

Significant submarine infrastructure is already installed on the seafloor of the New York Bight and New York Harbor as seen is Figure 2-1. Additional submarine cables will be installed to connect future offshore wind farms to the landside electrical grid. The frequency and severity of anchor strikes on existing submarine infrastructure, such as cables and pipelines, is not commonly known. Through this study, the M-TWG seeks to shed light on previous anchor strikes to understand the history, context, and lessons learned from those events. This report summarizes research on previous known and suspected anchor strikes. Research was based upon searches of incident reports filed with organizations such as the U.S. Department of Transportation Pipeline and Hazardous Materials Safety Administration (USDOT PHMSA), Maritime Alerting and Reporting Scheme (MARS), USCG, the New York State Department of Public Service, and media reports. However, given the remote nature of such incidents, it is likely that not every anchor strike is reported and the cause of damage to submarine infrastructure is therefore not classified as an anchor strike. To augment publicly available data, researchers conducted significant outreach to a number of organizations that own, operate, or regulate submarine infrastructure to draw upon internal knowledge of these events.

A list of 19 suspected anchor strike incidents along the East Coast of the United States was compiled, with the event dates spanning from 1969 through 2021. These 19 incidents are tabulated in the database provided in Appendix A.

Publicly available information about such incidents is limited, as a result the findings of this study were highly dependent upon cooperation and data provided by submarine infrastructure owners and operators. As such, this database should not be considered exhaustive. In the following subsections, four case studies of specific anchor strike incidents from the database were developed to provide a focused narrative for information. The limited depth of the publicly available information also influenced which incidents could be developed into case studies. To the extent possible, the case studies selected represent a variety of geographically relevant locations and submarine infrastructure.

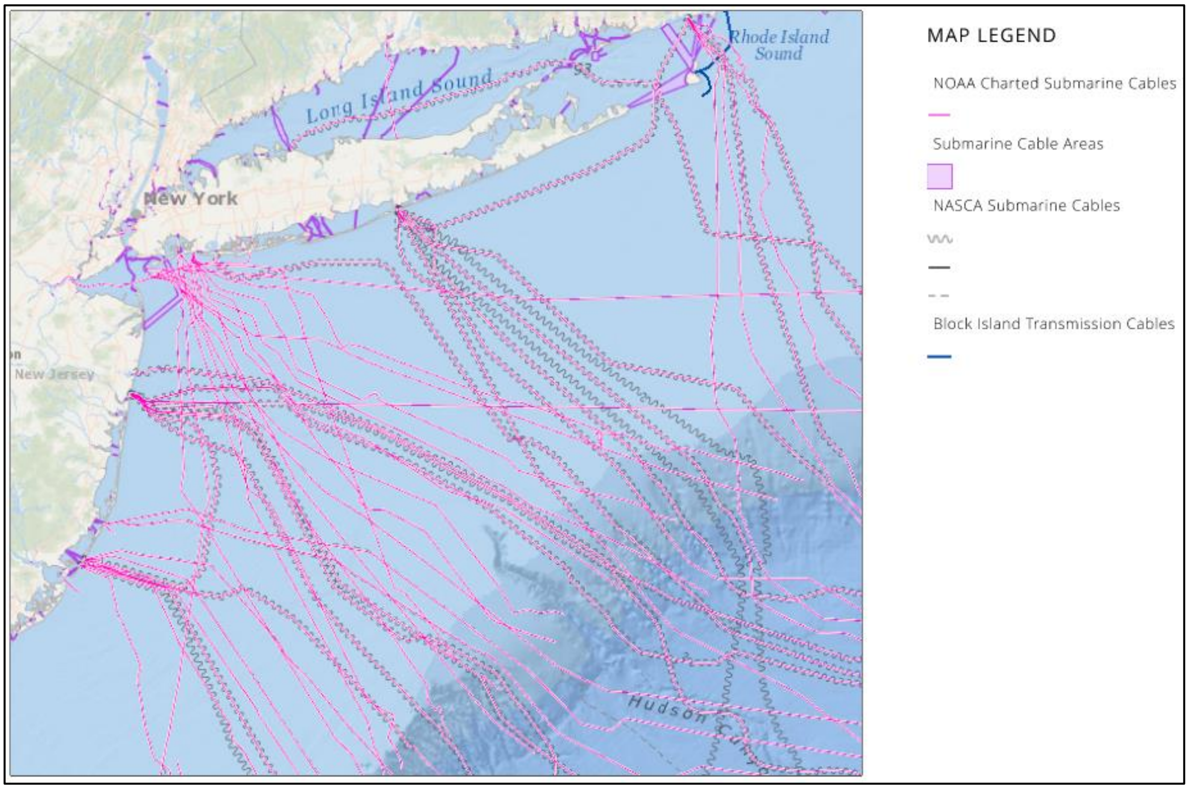

Figure 2-1 – Existing submarine infrastructure in the New York Bight, New York Harbor, and Long Island Sound (Ref. [8])

2.1 Case Study 1: Northport-to-Norwalk Cable (NNC), 2002

The Northport-to-Norwalk electric power cables were originally installed in Long Island Sound in 1969 and commissioned in 1970 between Northport, NY and Norwalk, CT. The cables were jointly owned by the Long Island Power Authority (LIPA) and Connecticut Light and Power Company (CL&P, also formerly known as Northeast Utilities, now Eversource) and operated by PSEG (held by Public Service Enterprise Group Inc.). The system consisted of seven (7) separate three-inch (3") diameter cables, each made up of a single solid copper core, paper insulation, lead covering, pressurized dielectric insulating fluid, and an external armoring. The cables, also known as the 1385 Line Cable System, were installed in water depths up to approximately 200 ft, and laid, unburied, over a sea floor consisting primarily of sand and silt, see Figure 2-2.

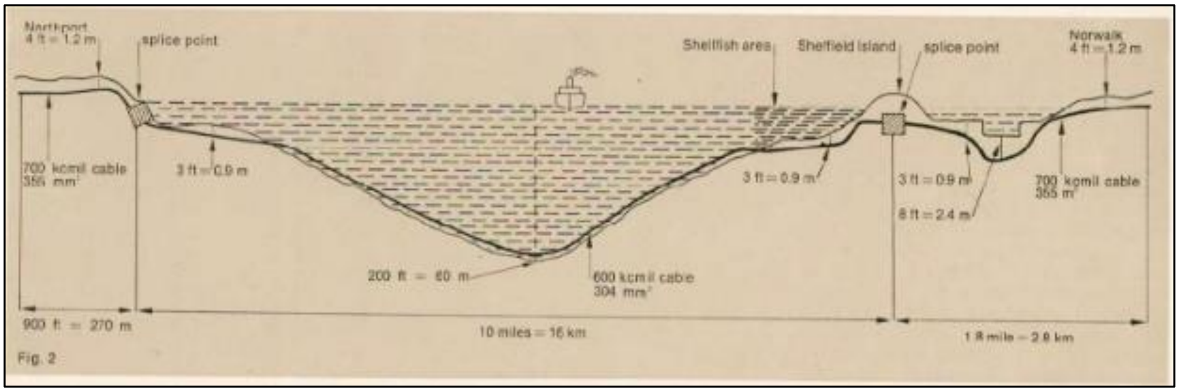

Figure 2-2 – Burial depth of original NNC cable, Ref. [9]

On November 17, 2002, a supply vessel, formerly known as *Mr. Sonny* (now named *RMC Citation*), struck four (4) of the seven (7) cables in approximately 50 ft of water depth. The 665-ton deadweight tonnage (DWT) vessel was installing a 36-mile natural gas pipeline between Northport and the Bronx as part of the Iroquois Gas Transmission System pipeline project when it dragged its anchor on the seabed during a Nor'easter storm with rough seas and wave heights of 8 to 10 ft. The vessel has two 6,000 lb aft anchors and two 7,000 lb forward anchors each with 3,800 ft of 1 in. cable. It is unknown which anchor struck the cables. The damage was extensive, and it was estimated that approximately 1,400 gallons of insulating fluid was released into the ocean. LIPA had jurisdiction over investigating the damage and overseeing the repairs as the incident occurred within approximately one-half mile from Northport, as can be seen in Figure 2-3. Following the incident, power was cut to the lines and prompt temporary repairs were completed, including capping the damaged cable ends. Permanent repairs were conducted in 2003. The impact to Long Island was minimal as power demands were low compared with peak summer demand.

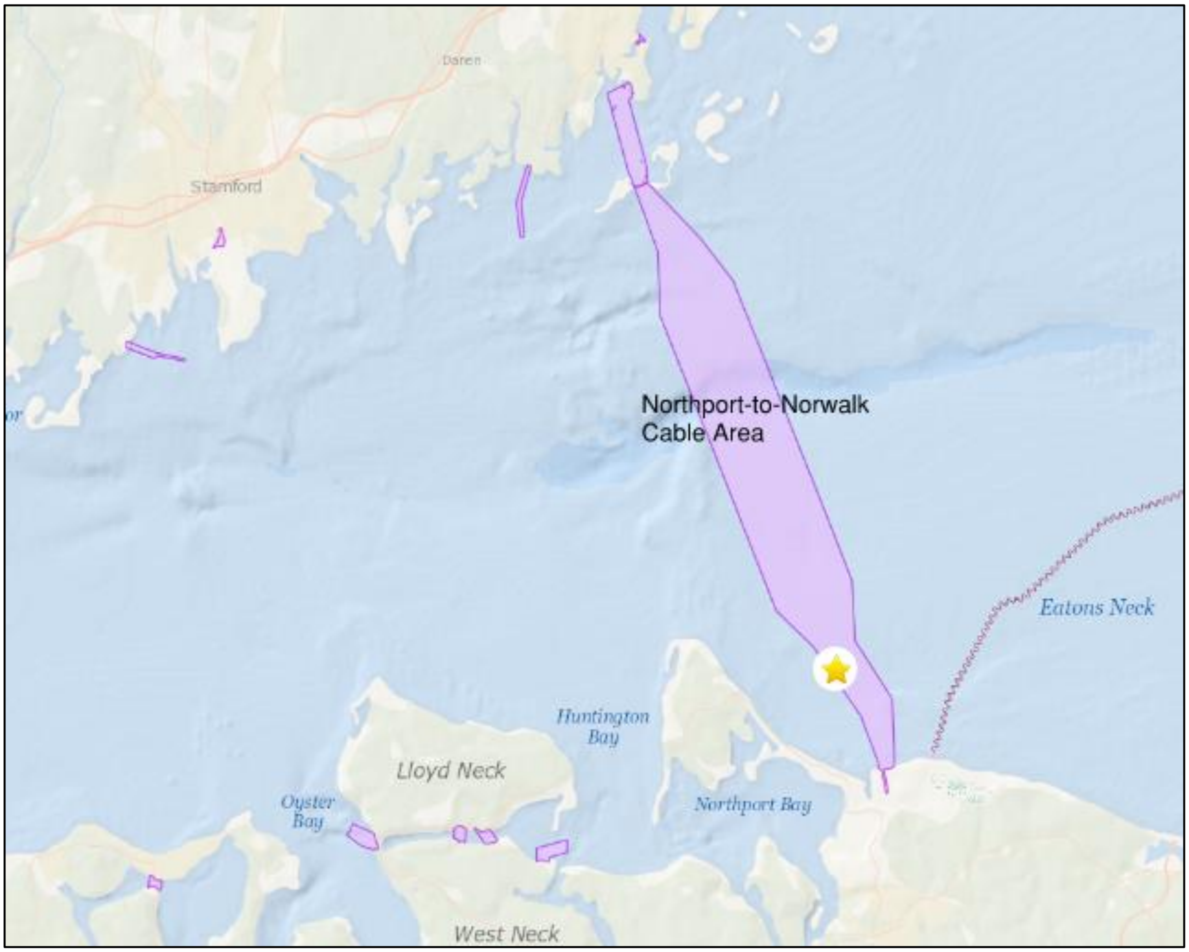

Figure 2-3 – Map of Northport-to-Norwalk Cable and approximate location of strike, base layer as per NOAA Ref. [10]

Litigation started in December 2002 when LIPA and CL&P pursued the vessel owner and other parties involved in the natural gas pipeline project. Voluntary mediation occurred in February 2005. LIPA, CL&P, and insurance underwriters reached a settlement agreement with the vessel owner and other parties, completed in April 2005. Details of the financial settlement were not discovered by this study.

The original cables have since been replaced in 2007-2008 by Northeast Utilities with newer XLPE (cross-linked polyethylene) with solid dielectric (not fluid) 3-phase cables, typically buried 3 to 10 ft below the seabed. Cable burial was completed using a Nexans Capjet hydro plow (see Figure 2-4). The replacement of the cable was a $140M project.

In August 2008, a settlement agreement for the LIPA application for NYS Article VII Certificate of Environmental Compatibility and Public Need appears to have agreed to, allowing the obsolete NNC cables to be drained, cut, capped, and abandoned for sections where LIPA was unable to conduct removal, and included a monitoring program spanning 10 years for benthic biology and bathymetric monitoring. The purpose of the monitoring program is to accurately assess the impacts (if any) of leaving the remaining retired cable segments buried within Long Island

Sound may have on benthic biology and surface bathymetry in the immediate vicinity of the abandoned cable segments. Additionally, LIPA was required to request the abandoned cables be noted on appropriate National Oceanic and Atmospheric Administration (NOAA) maps.

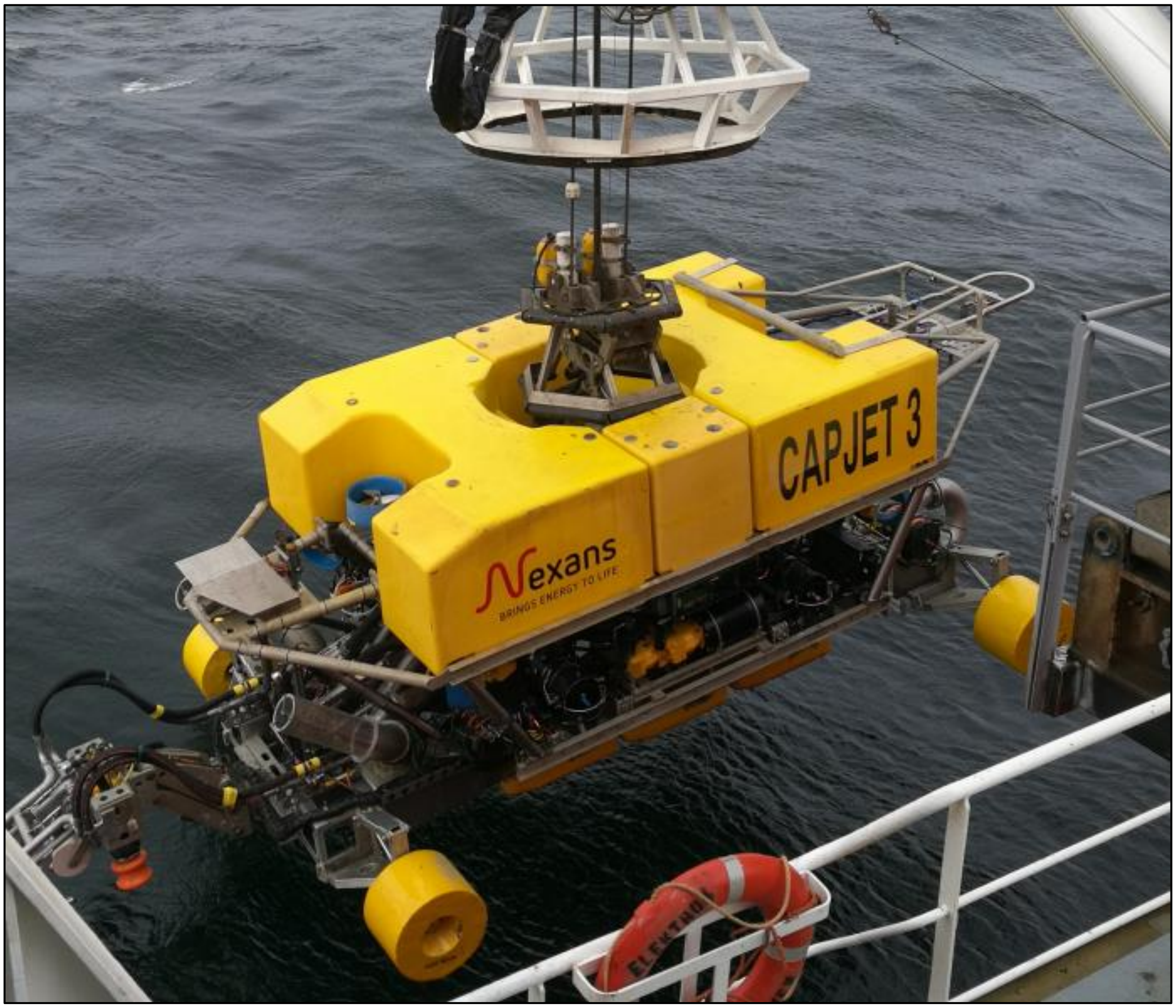

Figure 2-4 - Nexans Capjet Hydro Plow

Additional anchor strike incidents were reported by PSEG for the NNC between 1969 and 2002 at various locations, depths, and extent of damage. Details discovered by this study are provided in the Appendix A Database of Anchor Strike Incidents.

Several sources were used in researching this case study, refer to Refs. [11], [12], [13], [14], [15], [16], [17], and [18].

2.2 Case Study 2 & 3: Long Island Sound Transmission Cable Y-49, 2003 and 2014

The Y-49 Long Island Sound transmission cables were installed and placed in service in 1991, including the 8-mile section buried beneath Long Island Sound between New Rochelle, NY and

North Hempstead, NY as shown in Figure 2-5. The New York Power Authority (NYPA) owns the cables; they are maintained by LIPA as the primary user. The cables were buried an average of 10 ft and spaced approximately 600 ft apart in water depths up to 100 ft. The system comprises four (4) independent cables, consisting of three phases and a spare (A, B, C, spare), where the spare can be configured to replace any one of the three cables. Each cable is filled with DCL 45 dielectric insulating fluid, pressurized to 160 psi. The four-cable system operates at 345 kilovolts (kV) and can carry a maximum 675 MW of power, with an average operating load of 600 MW. Details regarding the installation including the installation tool were not discovered by this study.

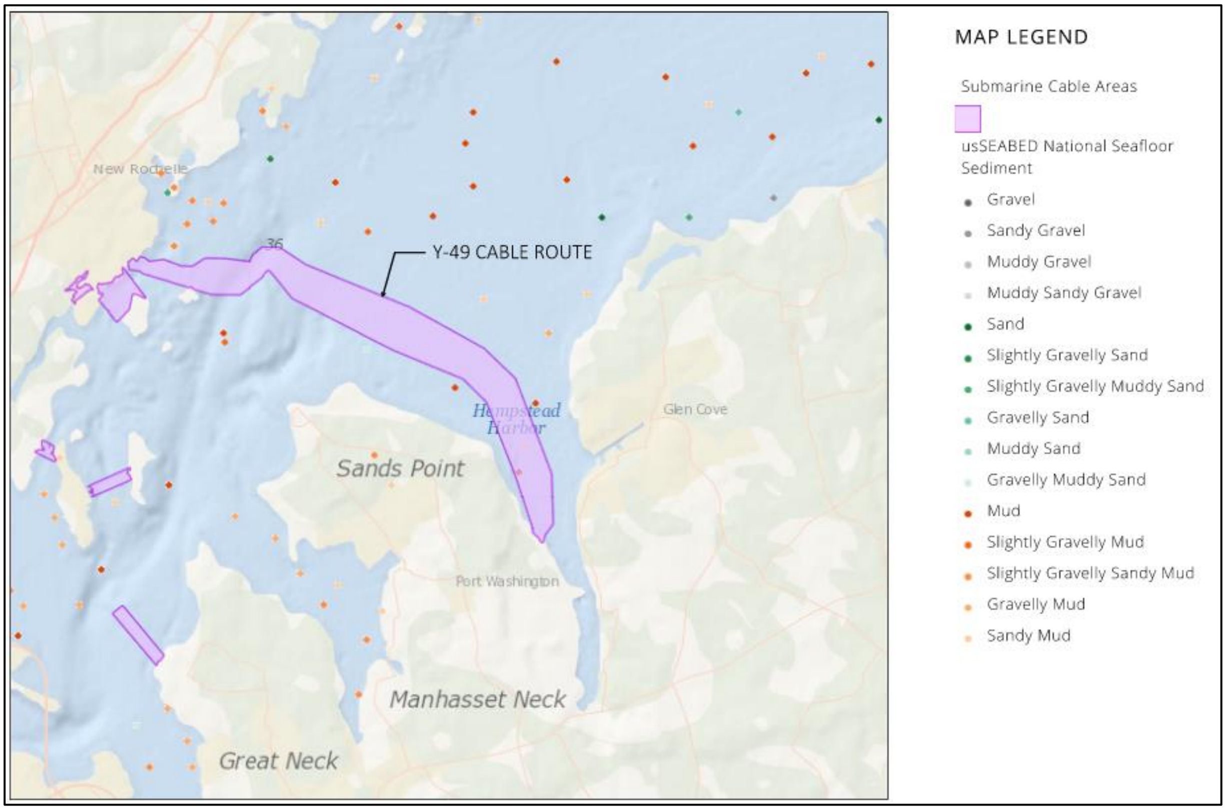

Figure 2-5 – Seafloor sediments in Hempstead Bay with Y-49 cable area, Ref. [19].

NYPA engaged Vesper Marine, an electronic navigation firm, to develop a virtual smart-buoy system designed to prevent damage to state-owned power lines by creating a virtual protective-zone system in 2016. The system collects vessel automatic identification systems (AIS) data using existing satellite-based electronic navigation technology to monitor and communicate with ships in the vicinity of the cables. The system automatically sends alerts to the vessel with increasing urgency if the vessel appears to be preparing to drop anchor, as well as notification to NYPA. See Figure 2-6 for cable route and alert areas highlighted. The system also records all the alert information, giving NYPA the ability to track history of events and vessel movements. To establish the virtual system of beacons costs about $75,000 and an annual fee to Vesper Marine to operate it.

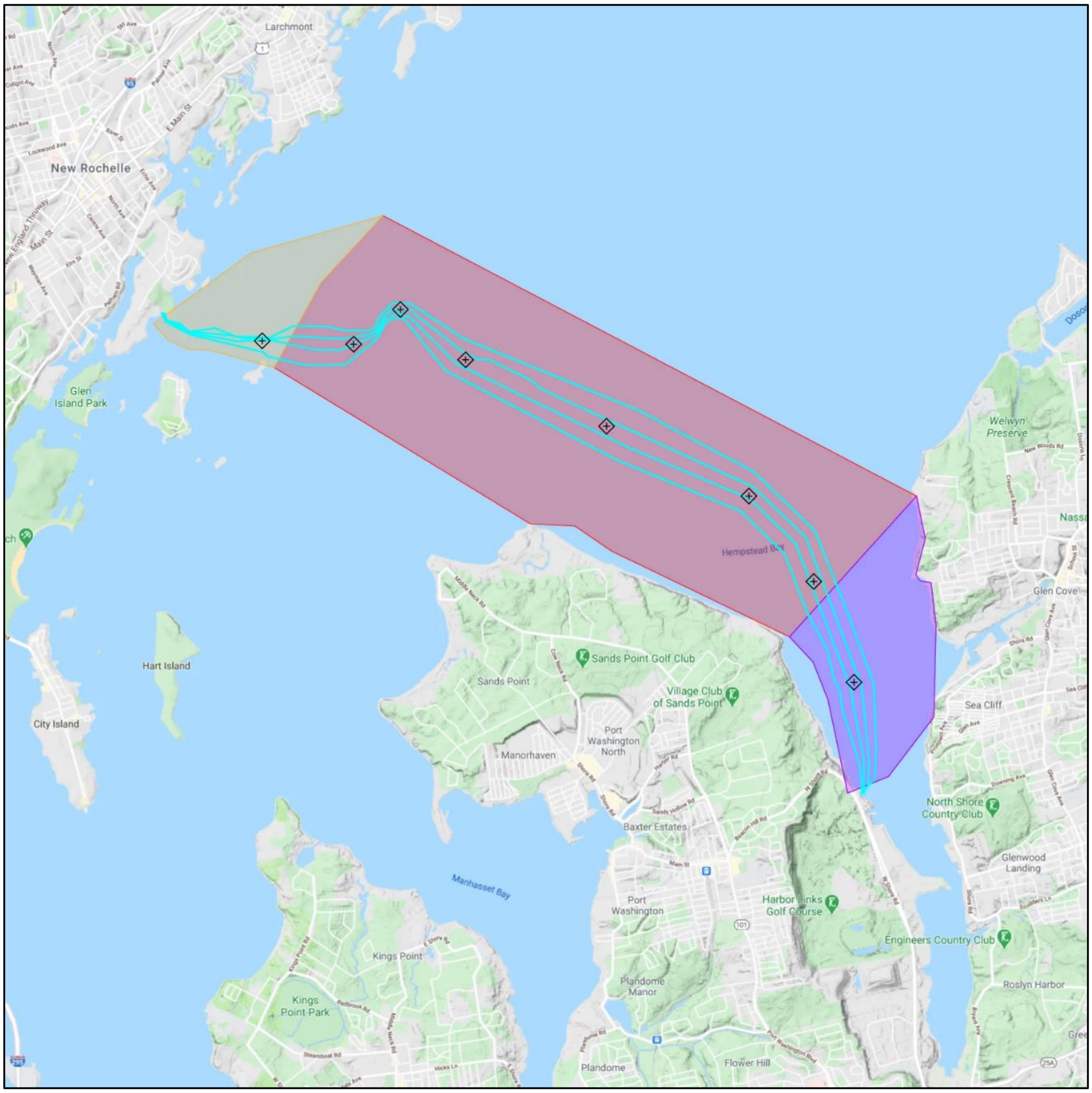

Figure 2-6 – Y-49 cable route with virtual protective zones identified, Ref. [20]

In April 2021, the Y-49 cable onshore equipment had been reported to be unreliable for the previous 6 months; however, the subsea portion of the cable is not reported to be an issue. Repair works were conducted in December 2020 and February 2021, but the issue has not been resolved.

Details of the anchor strikes are provided in Sections 2.2.1 and 2.2.2.

Several sources were used in researching these case studies, refer to Refs. [21], [17], [22], [23], [24], [25], [26], [27], [28], [29], [30], [31], [32], and [4].

2.2.1 Case Study 2: Y-49, 2003 Anchor Strike

In February 2003, the vessel *Gulf Horizon* reportedly dragged its anchor damaging one (1) of the four (4) Y-49 cables and causing a fault. The 1494-ton DWT vessel was working for the Iroquois Gas Transmission System pipeline project when it dragged its anchor on the seabed, causing the incident. The exact location of the incident was not discovered by this study. The *Gulf Horizon* vessel has since been scrapped in India, and the details of the vessel's anchor equipment were not discovered by this study. The cable damage was extensive, causing fluid leakage of over 2 gallons per hour and over 6,000 gallons of total fluid lost. Following the incident, power was cut to all cables. Temporary repairs were conducted within 10 days, which included capping the cables. Permanent repairs were completed by September 2003 and required splicing in a replacement section using a cable lay vessel. The total repairs and clean-up took seven (7) months and was reported to cost approximately $35M USD.

Litigation arising from the incident started in August 2003. NYPA and LIPA collectively filed claims asserting total damages of approximately $21-25M USD. The details of a financial settlement were not discovered by this study.

2.2.2 Case Study 3: Y-49, 2014 Anchor Strike

On January 6, 2014 the motor tug *Ellen S. Bouchard*, operated by Bouchard Transportation Co., struck the C-phase Y-49 cable (one (1) of the four (4) cables) in the transmission line causing a fault. The incident occurred when the captain of the vessel misread a navigation chart and intentionally lowered the 6,000 lb anchor in the cable area of Hempstead Harbor. The exact location of the incident was not discovered by this study; however, an approximate location is shown in Figure 2-7. The anchor penetrated the seabed 10 ft and damaged the cable at an approximate water depth of 35 ft. Bouchard Transportation Co. sold the 1,000-ton DWT tug in bankruptcy proceedings in 2021. The cable was temporarily capped on January 28, 2014, but the leak was not fully stopped until February 27, 2014. It was estimated that dielectric fluid was leaking at a peak of 50 gallons per hour, for a total of approximately 66,000 gallons of fluid loss. Power was cut to all cables following the incident and electricity transmission was brought back to full operation by January 16, 2014 through the fourth spare cable. The damage was extensive and reportedly cost $35M USD in repairs and clean-up. Permanent repairs required splicing a 200 ft long replacement section by means of a cable lay vessel.

Figure 2-7 – Approximate location of damaged cable shown with red dot, Ref. [31]

NYPA filed a complaint on January 31, 2014 in the United States District Court for the Southern District of New York, and the case worked its way through the courts until parties entered mediation and reached a settlement that was executed in September 2020. NYPA claimed damages of $22.2M USD and LIPA claimed damages of $2.6M USD, however LIPA's claims were dismissed as LIPA is not the owner of the cables. Bouchard's insurer paid the amount agreed to under the settlement the same day Bouchard began Chapter 11 bankruptcy proceedings. Details of the actual financial settlement were not discovered by this study.

2.3 Case Study 4: Central Hudson Gas and Electric Poughkeepsie Kingston (PK) Pipeline

The Poughkeepsie to Kingston natural gas pipeline, owned by Central Hudson Gas and Electric, was installed in 1931. The route of the pipeline traveled from the Poughkeepsie receival station in Poughkeepsie, NY, going west across the Hudson River to just north of the Poughkeepsie railroad bridge, and then continues north along the west shore to the Kingston holder station in Kingston, NY. The river crossing is 3125 ft shore-to-shore and supplies natural gas to residential and commercial customers. The pipeline was installed directly on the riverbed with some cover, but the depth of trenching is unknown as there were no requirements for burial at the time of installation. The pipeline is an 8-inch diameter distribution pipeline that operates under a maximum allowable operating pressure of 60 psi.

On the morning of August 8, 1999 the anchor and anchor chain from the *Maria T* cement barge severed the pipeline while under tow (being pushed) by the *Scott Turecamo* towing vessel. The anchor flukes caught the PK pipeline and severed it while travelling at 6 knots. The weather at the time of the event in Poughkeepsie was clear with unlimited visibility and 80°F with light winds. The location of the strike occurred near Poughkeepsie at the Poughkeepsie Railroad Bridge, now known as the Walkway over Hudson (refer to Figure 2-8 for approximate location). The *Maria T* also passed over three other natural gas pipelines while dragging anchor; however, damage was only reported to the epoxy coating of Tuxedo Poughkeepsie (TP) line and minor rock cover damage on the other two lines.

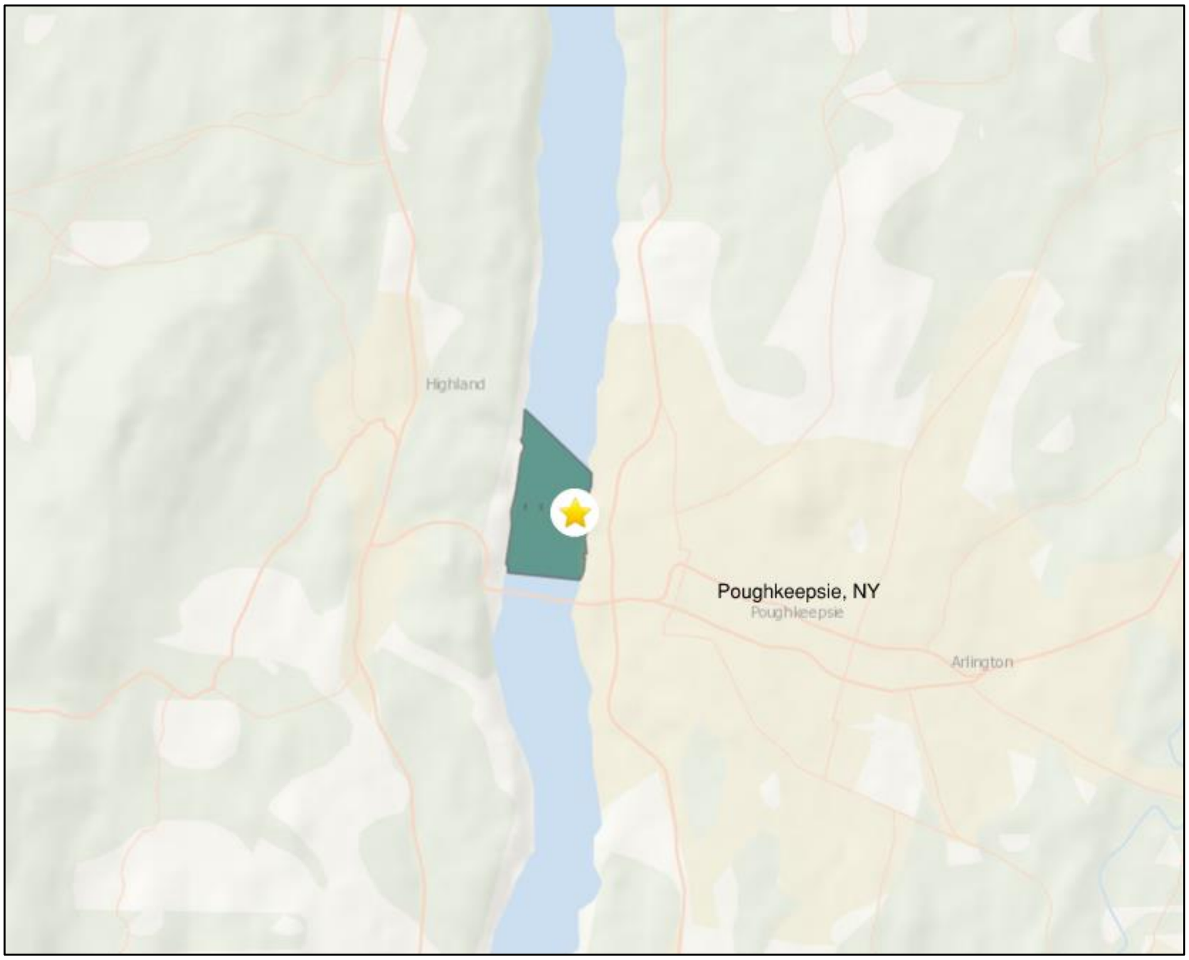

Figure 2-8 – Map of Poughkeepsie to Kingston Pipeline and approximate location of strike, base layer as per NOAA Ref. [10]

The *Maria T* has 8865 net tonnage and a 4500 lb fluke anchor with 7 shots (630 ft) of 2.25-inch anchor chain. The anchor that struck the PK pipeline was located on the starboard bow of the vessel. Figure 2-9 is a photo of the anchor directly following the event. Natural gas was released as a result of the damage, causing the water to bubble. Twenty-five people were evacuated from the area, and the waterway was closed for four hours as a precaution. Central Hudson Gas and Electric shut down flow of gas to the severed pipe following the incident. The prompt action of witnesses and Poughkeepsie Police to call the barge and request that they check the anchor prevented further damage to additional pipelines (4 inch and 8 inch) 15 miles down the river from where the *Maria T* was stopped.

Figure 2-9 – Maria T cement barge anchor showing debris picked up from dragging anchor on riverbed, taken August 8, 1999, Ref. [33]

A full investigation was conducted by the United States Coast Guard and classified it as a Serious Marine Incident. Divers were sent to survey the damage and found the PK pipeline severed and approximately 300 ft of its length was damaged. The incident report details the events leading up to and following the anchor strike including anchor operation, testing and repair history, activities onboard the vessel, and voyage details in the days prior to the event. A summary of some of the conclusions of the report are as follows:

- The *Maria T* anchor brake tension was released such that it would not hold the anchor in its hawser while transiting.
- The *Maria T* anchor brake was not properly set such that the end of the tell tail indicator lined up with the after side of the spring plate. Furthermore, operators on the vessel did not know how to align the tell tail indicator to assure the correct setting and did not check the status of the anchor brake when the barge departed.
- The release of the anchor was not a result of failure in the control of the remote-controlled anchor release system.

- The crew of the *Scott Turecamo* towing vessel was responsible for arranging and using the anchor of the *Maria T* as they saw appropriate for the transit.
- The *Scott Turecamo* crew and operating company did not document procedures for crew to carry out their tasks, including setting the anchor and verifying the anchor did not let go, nor were there operating guidelines for towing barges with remote anchor release systems.
- If the pipeline was installed under more recent installation standards, trenching would be required to minimum 2 ft below the riverbed, and damage would have been mitigated.

The minor damage to the TP Line was repaired by applying a new epoxy coating to the damaged pipe segments, and rock cover was replaced over the other two lines. The PK line was abandoned with metal blanks inserted at the shoreside flanges after decontamination with a solvent wash and then backfilled with grout or high-density foam cement to mitigate PCB contamination. The case text reports that there was no evidence to suggest that the pipe sections remaining in the Hudson River were likely to become a hazard to navigation in the foreseeable future (Ref. [34]).

Litigation by Central Hudson Gas Electric Corporation pursued the *Maria T*, the *Scott Turecamo,* Moran Towing Corporation (owner/operator of the *Scott Turecamo*), and LaFarge Building Materials for damages. It was determined that Central Hudson sustained damages of $650,471.75; however, Central Hudson was found comparatively negligent and assigned 25% responsibility for the damage as a result. Central Hudson was awarded $487,853.82 plus pre-judgement interest on $284,837.25 at 3.73% compounded annually from Sept. 1, 1999 to the date of judgement July 25, 2007. The 25% comparative responsibility is a result of findings that in 1983 and again in 1991 a dive survey conducted found that the PK natural gas pipeline had significant amounts of exposure (480 ft) and suspension (110 ft) of at least 4 feet above the bottom in some areas. The surveyor had recommended that the suspensions exceeding 20 ft be stabilized using cement bag piers and warned that a line suspended above the river bottom may be subject to damage by drifting debris and ships' anchors. Central Hudson took no further actions prior to the anchor strike to protect the PK line per the recommendations of the 1991 dive survey, resulting in the 25% assigned responsibility, Ref. [34].

Several sources were used in researching this case study, refer to Refs. [34], [33], and [35].

3 Anchor Penetration

Accurately quantifying anchor penetration depth is critical to informing the burial depth of submarine infrastructure (e.g. cables) and determining the risk of an anchor strike at varying cable burial depths. The intent of this anchor penetration section is to present findings from research into existing methods of calculating anchor penetration depth, and to estimate the depth of penetration for vessels/anchors commonly occurring in the New York Bight and New York Harbor. This task does not evaluate risk of an anchor strike or make any judgment on the probabilities of an anchor deployment, an incident occurring, or external factors that could influence vessel behavior in an emergency situation, such as water depth, bathymetric profile, presences of obstacles, etc. Analyses of cable burial risks and specific burial depth recommendations are beyond the study's scope.

In order to estimate anchor penetration depths, this study researched and reviewed publications, standards documents, and academic papers to evaluate existing methods of estimating anchor penetration into the seabed. Two general scenarios were examined:

- Dropped anchor – the anchor is released and is assumed to fall vertically, making a direct impact on top of the seabed.
- Dragged anchor – the anchor is released and dragged by the moving vessel so that the anchor flukes dig into the seabed, as shown in Figure 3-1.

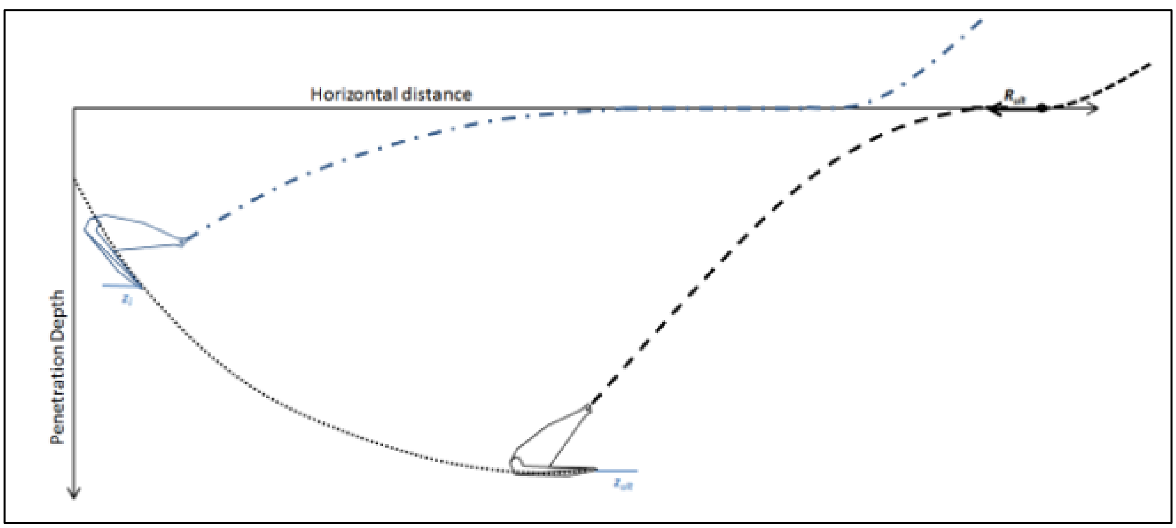

Figure 3-1 – Illustration of drag anchor behavior (Ref. [36]).

The dropped anchor scenario covers the initial release, vertical fall, and initial impact upon the seabed of a vessel's anchor. Once the anchor lands on the seabed, it is followed by the dragged anchor scenario. In this scenario, an anchor will continue to dig deeper into the seabed until either the vessel comes to a halt, the anchor hardware breaks, or the anchor pulls out of the seabed. As illustrated in Figure 3-1, the greater the horizontal distance traveled, the deeper the vertical penetration beneath the seabed surface.

3.1 Sediment Types

Anchor penetration depth is heavily dependent upon the type of sediment that the anchor encounters. For example, an anchor, whether will typically penetrate much further into soft clay or silt than it will into dense sand, stiff clay, or gravel when it is dropped and dragged.

Note that the methodologies examined in this study for estimating anchor penetration consider only one uniform sediment type. Therefore, the sediment information referenced by this study only reflects surficial sediments. For the purposes of this study, the thickness of this top layer is assumed to exceed the maximum depth of anchor penetration. In reality, however, one or more sub-layers of sediments with differing properties would affect the anchor behavior, trajectory, and penetration depth, should they be encountered.

Based on review of the Ref. [37] surficial geology map (reproduced in Figure 3-2 below) and seafloor sediment data collected by the USGS (Ref. [38]) (Figure 3-3, Figure 3-4, and Figure 3-5), the seabed in the New York Bight is comprised primarily of sand of varying density. In addition to sand, areas of soft sediments (i.e. mud/silt) do exist, especially in New York Harbor, the Hudson River, and the western half of Long Island Sound. Therefore, anchor penetration into both sand and soft sediments is considered.

For context, Appendix J of the Empire Wind (EW) Construction and Operations Plan (COP) (Ref. [39]) identifies the average sediment classification along the export cable routes. For the EW 1 cable route, the length of cable that passes through Lower New York Bay will be buried in riverine sediments of approximately 62% silt and clay with the remaining 38% coarse-to-very fine sand. The remaining EW 1 cable length and all of the EW 2 cable are assumed to be buried in non-riverine sediment that consists of only approximately 10% silt and clay (90% coarse-to-very fine sand).

Appendix H of the Sunrise Wind COP (Ref. [40]) identifies the average sediment classification along the export cable route as 94.4% sand, 3.3% gravel, and 2.3% fine-grained material in NYS waters and 83.1% sand, 13.2% gravel, and 2.3% fine-grained material in federal waters. These are averages of all sample points, and there are numerous points in federal waters that have 50%-75% fines.

Appendix I of the South Fork Wind Farm COP (Ref. [41]) identifies the average sediment classification along the export cable route as approximately 90% sand and gravel and 10% silts and clays in vibracore samples taken to a depth of 1.8m.

It is important to note that these classifications identified in the Empire Wind, Sunrise Wind, and South Fork Wind COPs are for the purpose of sediment transport modeling, and the strength properties of the sediments are not identified.

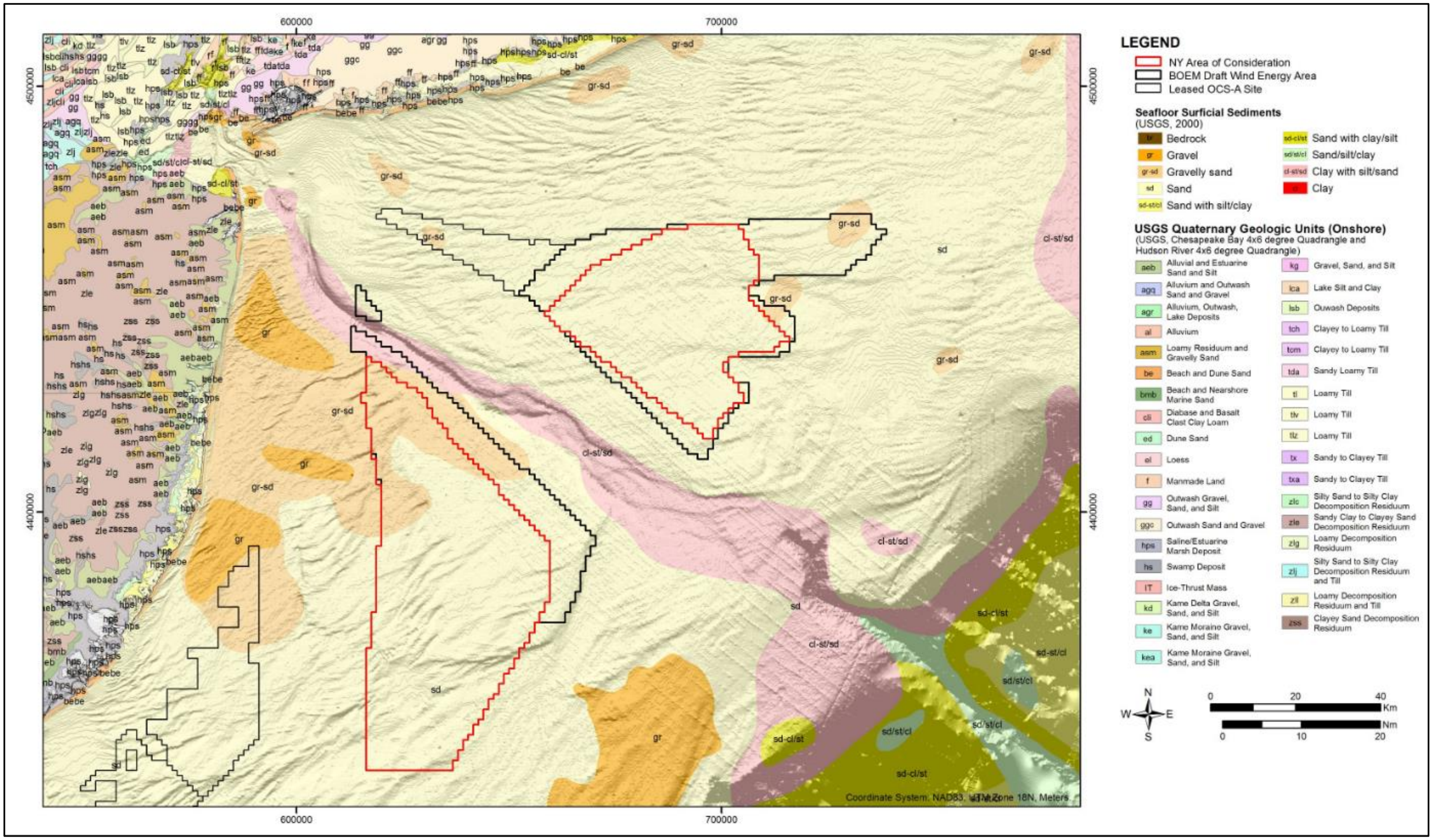

Figure 3-2 – Surficial geology of New York Bight (Ref. [37])

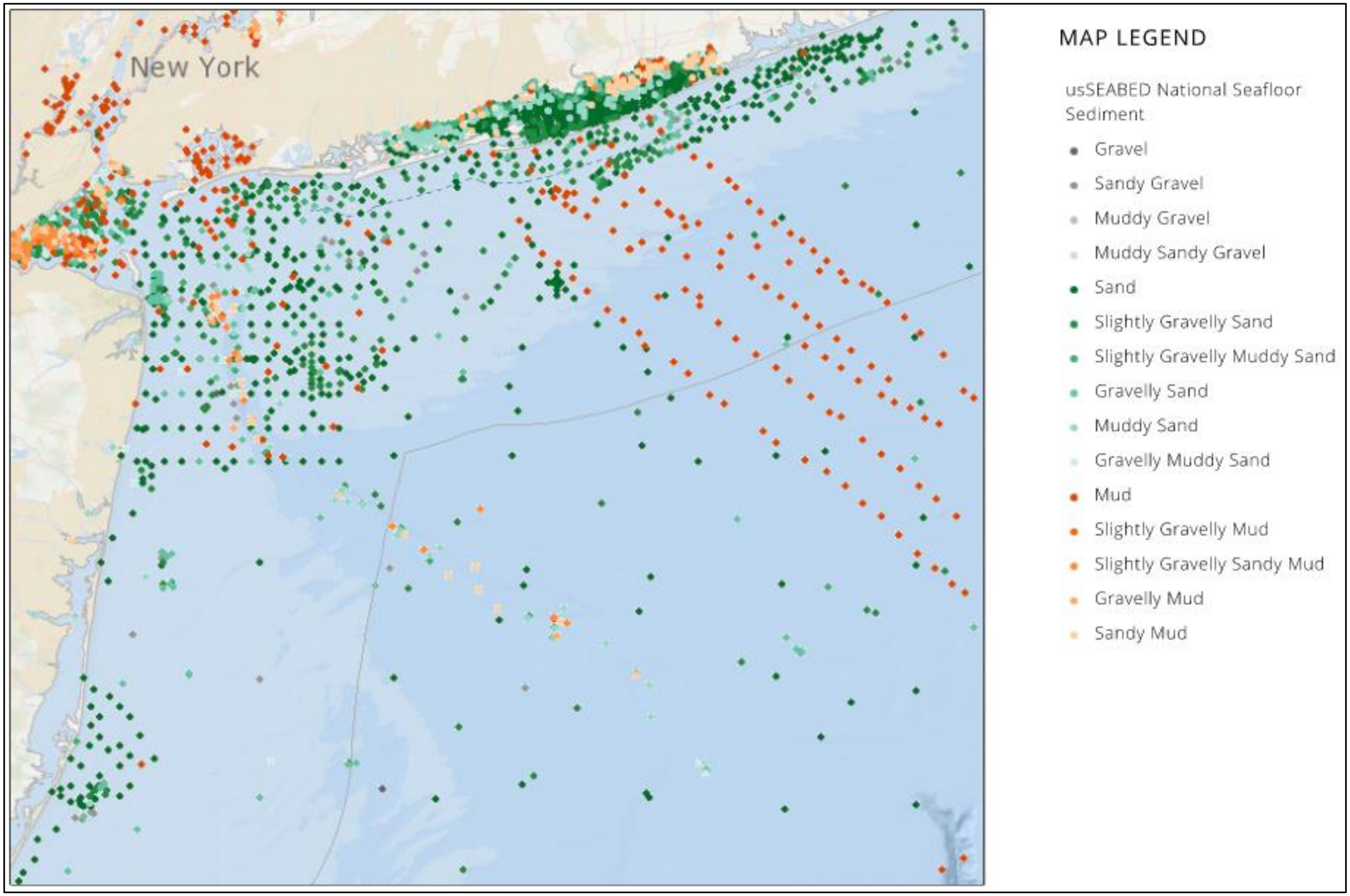

Figure 3-3 – Seafloor sediments of New York Bight (Ref. [42])

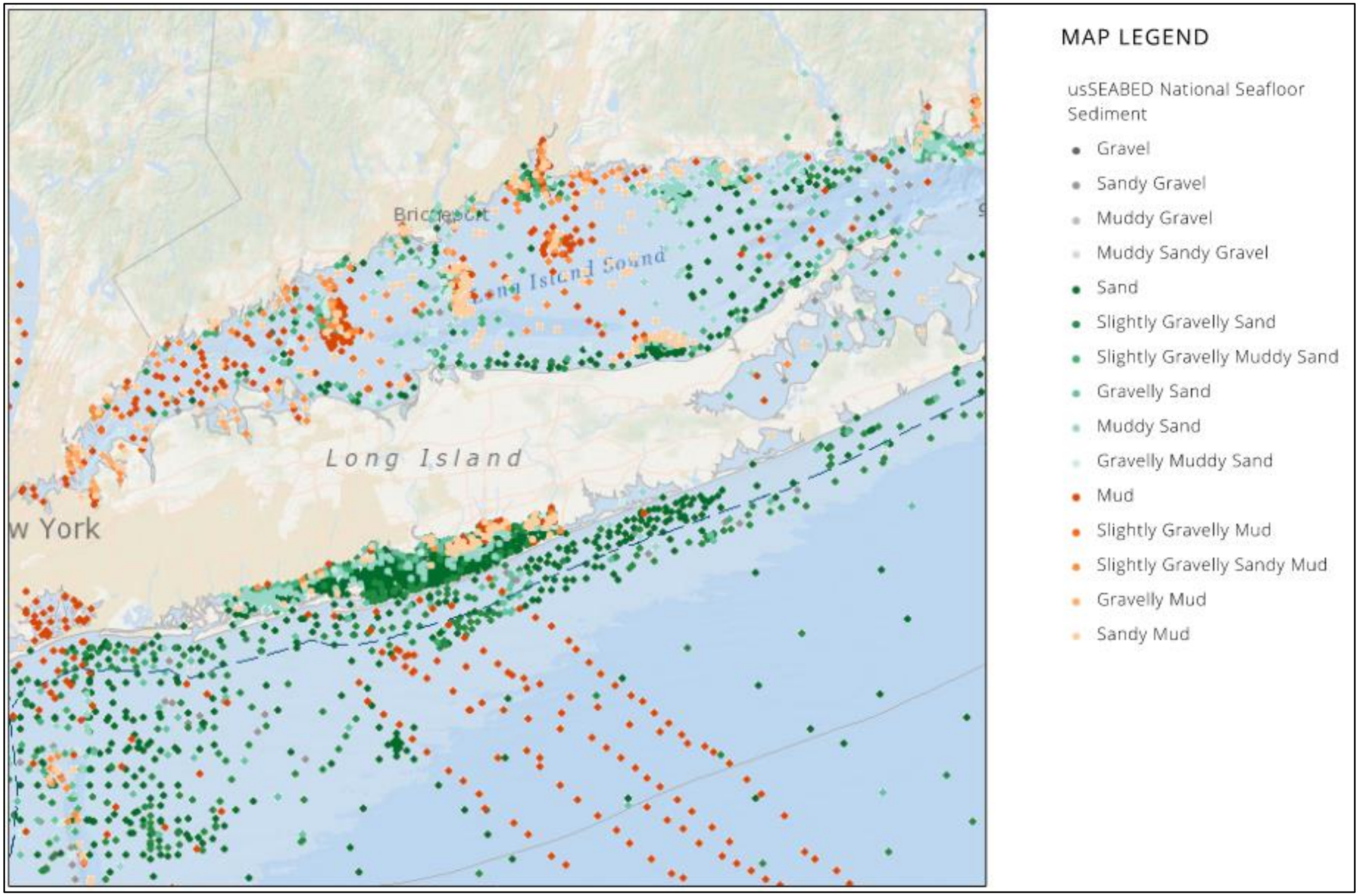

Figure 3-4 – Seafloor sediments of Long Island Sound (Ref. [42])

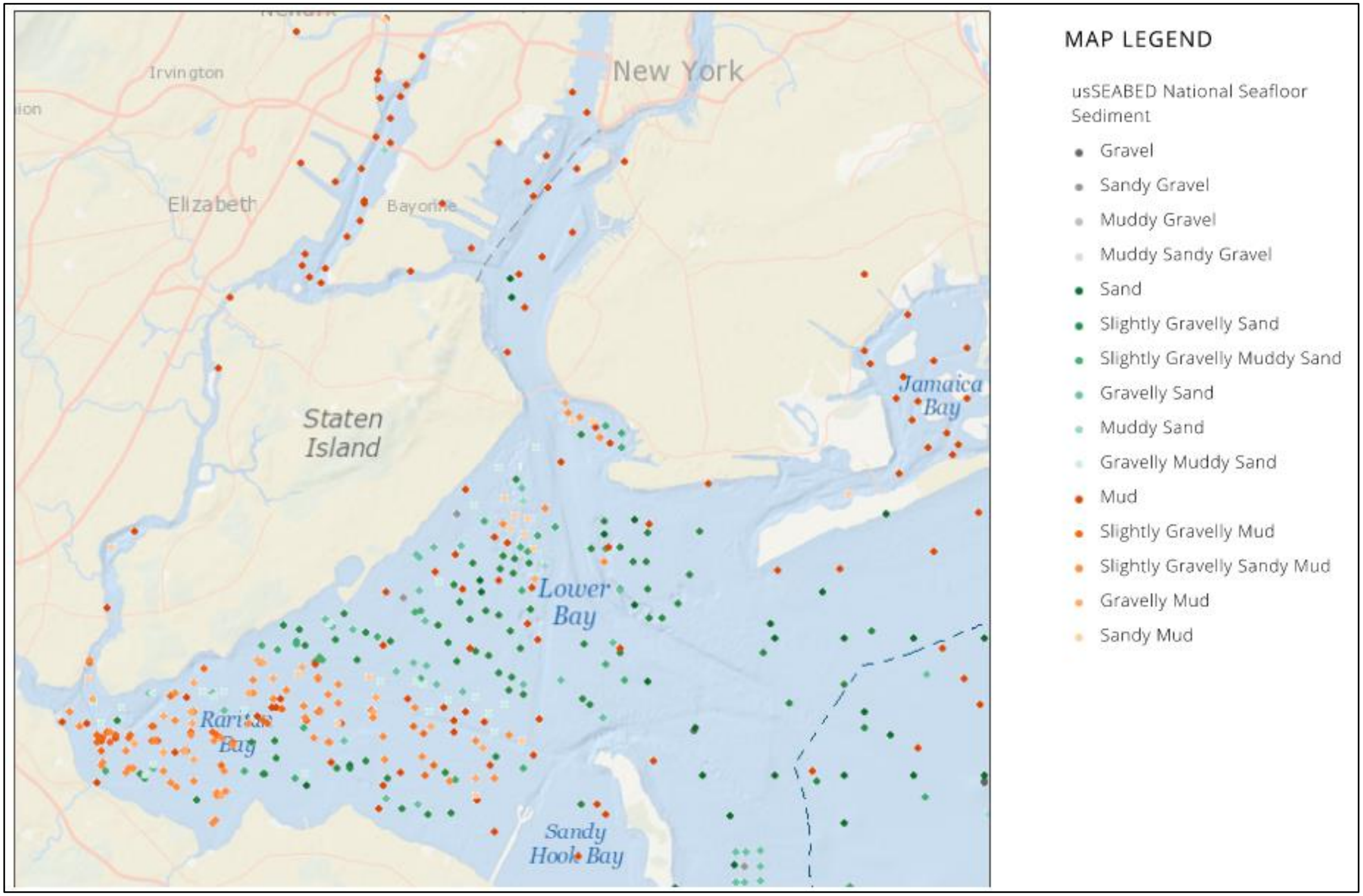

Figure 3-5 – Seafloor sediments of New York Harbor (Ref. [42])

3.2 Vessels

Vessels considered in this study are limited to large commercial vessels that commonly operate in the New York Bight and New York Harbor along with vessels that are anticipated to begin visiting the region in the near future. These vessels would therefore be expected to carry large anchors capable of penetrating deep into the seabed. These vessels include but are not limited to those shown in Table 3-1. This analysis was not intended to capture every possible vessel and anchor type that may occur in and around the New York Bight; rather, the focus was on vessel and anchor combinations most likely to be observed.

Table 3-1 – Classes of commercial vessels expected to operate in the New York Bight and New York Harbor

Vessel Class	**Typical DWT** (Ref. [1] unless noted otherwise)
Seawaymax (tanker)	10,000 – 60,000
Handysize (cargo)	28,000 – 40,000
Handymax (tanker or bulk)	40,000 – 50,000
Panamax (tanker or cargo)	60,000 – 80,000
Aframax (tanker)	80,000 - 100,000
Ultra Large Container Vessel (~8,000-10,000 TEU*)	100,000 - 120,000
Super Ultra Large Container Vessel (14,000+ TEU*)	160,000 - 170,000
Capesize (cargo)**	100,000 – 200,000
Suezmax**	120,000 – 200,000
Notes: *TEU refers to twenty-foot equivalent units, an indicator of a vessel's cargo capacity, and indirectly, size. **Capesize and Suezmax vessels do not currently commonly operate in the NY Bight / NY Harbor; however, due to approximately similar DWT, they were included with this analysis as being potentially indicative of the anchoring equipment found on the latest generation of 18,000 TEU+ container vessels.	

3.3 Calculation Methods

Analytical methods for predicting anchor penetration for both the dropped and dragged anchor scenarios were researched to find methods that suit the needs and constraints of this study. It was desired that the methods would consider appropriate variable input parameters, such as sediment properties and anchor weight and dimensions, so that the output can be considered representative of scenarios that may be encountered in the New York Bight and New York Harbor. On the other hand, the number and specificity of inputs should be limited to appropriately reflect the approximate nature of these estimates due to factors like the absence of detailed geotechnical parameters representing the actual conditions across the entire study area.

3.3.1 Dropped Anchor Scenario

References and publications reviewed include those listed in Table 3-2.

Table 3-2 – References for estimating dropped anchor penetration.

Reference	Methodology	Applicability - Cohesive Sediments	Applicability - Cohesionless Sediments
NAVFAC SP-2209-OCN Handbook for Marine Geotechnical Engineering [43]	Iterative analytical procedure. Predicts penetration by balancing energy of falling object vs. resistance of soil and hydrodynamic forces.	Applicable, but less accurate for penetrators that are not long, slender objects	Applicable, but accuracy not as good as for cohesive sediments
Hazard Analysis (Saveur), Tunnelling and Underground Space Technology [44]	Applicable to penetration into roof of concrete tunnel.	Not applicable	Not applicable
DNVGL-RP-F107 Risk Assessment of Pipeline Protection [45]	Cursory equations for dropped object energy and absorption by gravel. Focus of document is on risk/probability of impact.	Not applicable	Applicable to gravel only
Buried Depth of a Submarine Pipeline Based on Anchor Penetration (Zhu), Journal of Marine Science and Engineering** [46]	Iterative analytical procedure. Predicts penetration by balancing energy of falling object vs. resistance of soil and hydrodynamic forces. Simplified regression equations from analytical and experimental data.	Applicable	Applicable
D12-B to D15-FA-1 Risk Assessment and Dropped Object Analysis, Enersea* [47]	Iterative analytical procedure. Predicts penetration by balancing energy of falling object vs. bearing capacity of soil.	Applicable	Applicable
Notes: *Selected method **Insufficient information in reference to recreate analytical method.			

The method selected for estimating penetration depth in the dropped anchor scenario is the procedure laid out in Section 7.4.3.2 of the Ref. [47] report. This method is similar to other methods researched, and the Enersea report most clearly laid out the calculation procedure so it could be easily replicated. In this method, the kinetic energy of the anchor falling through water is calculated, which assumes the anchor is dropped from sufficient height to achieve terminal velocity (i.e. the buoyancy and drag force on the anchor balance with the downward gravitational force). The energy that the seabed absorbs upon impact is also calculated using a method derived from the Brinch-Hansen method of determining soil bearing capacity, which varies with depth (Ref. [47] and [48]). The downward movement of the anchor stops when the kinetic energy equals the seabed energy absorption at a certain penetration depth. Note that the purpose of these calculations is to estimate the point at which physical contact would occur between the dropped anchor and buried item. A scenario in which a buried item could be damaged by forces transmitted through the sediment even if an anchor stops short of making direct contact is not considered. Results are summarized and presented graphically in Section 3.4.1.

3.3.2 Dragged Anchor Scenario

References and publications that were reviewed include those listed in Table 3-3.

Table 3-3 – References for analytical methods of estimating dragged anchor penetration

Reference	Methodology	Applicability - Cohesive Sediments	Applicability - Cohesionless Sediments
ABS Design and Installation of Drag Anchors and Plate Anchors [49]	Predicts anchor rotation and translation trajectory through sediment vs. distance.	Applicable to soft to medium-stiff clay; not to stiff clay	Not applicable
On the Dragging Trajectory of Anchors in Clay for Merchant Ships (Zhuang et al.), Journal of Marine Science and Engineering [50] **	Mathematical model of anchor chain and anchor-soil interaction. Equations are iteratively solved until equilibrium is reached.	Applicable	Not applicable
The Performance of Drag Embedment Anchors (Aubeny et al.), Offshore Technology Research Center, Texas A&M University [51] **	Mathematical model to predict drag anchor trajectory compared with scaled experimental results.	Applicable to soft normally to over-consolidated clays	Not applicable
DNVGL-RP-E301 Design and Installation of Fluke Anchors [36] **	Procedure for calculating drag anchor resistance involves predicting anchor trajectory, but guidance on procedure is incomplete.	Applicable to soft to stiff cohesive soils	Not applicable

Reference	Methodology	Applicability - Cohesive Sediments	Applicability - Cohesionless Sediments
The Digging and Holding Capacity of Anchors (Miedema et al.), World Dredging Conference XVIII [52] **	Analytical model for calculating anchor resistance, byproduct of which is determining drag anchor depth	Applicable	Not applicable (behavior in sand discussed, but method is no appropriate for predicting embedment depth)
Notes: *Selected method **Insufficient information in reference to recreate analytical method.			

Unfortunately, none of the analytical procedures outlined in the Table 3-3 publications are applicable to cohesionless sediments (i.e. sand and gravel). Indeed, according to DNVGL-RP-E301 (Ref. [36]),

> *"there are neither well-established theories nor numerical tools to predict anchor behaviour in other soils than soft clay as per today, the theory presented… is only valid for soft to stiff cohesive soils. For other soils, other methods such as compiling results from anchor tests in comparable soils or using higher test tension will have to be used."*

Therefore, the dragged anchor scenario was estimated using empirical data and relationships from the sources listed in Table 3-4.

Table 3-4 – References for empirical methods of estimating dragged anchor penetration

Reference	Methodology	Applicability - Cohesive Sediments	Applicability - Cohesionless Sediments
Design Guide for Drag Embedment Anchors (NCEL TN-N-1688) [53] *	Correlates fluke length to penetration depth	Applicable	Applicable
Offshore Electrical Cable Burial for Wind Farm: State of the Art, Standards and Guidance & Acceptable Burial Depths, Separation Distances and Sand Wave Effect (Sharples), Bureau of Ocean Energy Management (BOEM) [1] *	Estimated anchor penetration for 9 vessel classes vs 3 soil types based on literature review	Applicable	Applicable

Reference	Methodology	Applicability - Cohesive Sediments	Applicability - Cohesionless Sediments
Cable Burial Risk Assessment Methodology: Guidance for the Preparation of Cable Burial Depth of Lowering Specification, The Carbon Trust [54] *	Estimated penetration for 10 vessel sizes (incl. DWT, typical anchor mass) vs 2 soil types. Estimating method not identified.	Applicable	Applicable
Notes: *Selected method **Insufficient information in reference to recreate analytical method.			

Based on references reviewed, the numerical relationships between anchor fluke length and drag penetration depth presented in Table 6.1 of the Ref. [53] Naval Civil Engineering Laboratory (NCEL) design guide appear to be most widely accepted for estimating penetration depth. Therefore, most of the data points included in Section 3.4.2 for the dragged anchor scenario are based on these relationships since the NCEL relationships allowed data points to be easily generated using a variety of anchor fluke lengths obtained from manufacturer catalogues that correspond with expected anchor sizes that are carried by vessels described in Section 3.2. The drag anchor penetration depths presented in Table 7.2 of the Ref. [1] report and Table 9 of the Ref. [54] report are also included in the data presented in Section 3.4.2. Results are summarized and presented graphically in Section 3.4.2.

These empirical relationships are based on the expected penetration depth an anchor will achieve when the anchor achieves its full capacity (Ref. [53]). That is, the anchor hardware will either fail or the anchor will pull out if the vessel has not stopped moving after this point. In a real-world dragged anchor scenario, such as an anchor deployment in an emergency situation, variables such as the initial speed of the vessel will dictate what horizontal distance the anchor will be dragged, and therefore vertical depth it will achieve, prior to the vessel stopping. However, this could occur prior to the anchor reaching its full holding capacity. Because the empirical relationships used in this study assume that full anchor capacity is achieved, consideration of variables like initial vessel speed are not relevant to this approach. Vessel speed will vary significantly across this large study area, so for the purposes of this study, an approach that does require consideration of such variables is desirable.

3.4 Results

The seabed penetration depths for both the dropped and dragged anchor scenarios are highly dependent on sediment type and anchor dimensions. For the two scenarios, three types of stockless anchors were considered: U.S. Navy (USN), Hall, and Baldt. Masses of the anchors examined range from 450 kg to 15,900 kg (992 lbm [pound-mass] to 35,054 lbm) to account for the range of vessel sizes that operate in the study area. Given that the input geotechnical information is based on general descriptions of seabed surficial sediments rather than detailed geotechnical investigations, and the calculation methods themselves are approximate in nature, these results should be considered rough order of magnitude estimates rather than specific predictions.

3.4.1 Dropped Anchor Scenario

A graph that plots anchor mass vs. penetration depth in sandy/silty clay, sand, gravelly sand, and gravel for the dropped anchor scenario is shown in Figure 3-6. In addition to the estimated properties of the four sediment types considered, the sediment bearing capacity is a function of the area of the anchor contact surface, which varies with anchor type. Two of the three stockless anchors considered, the USN and Hall anchors, have similar dimensions and their corresponding penetration depths therefore follow a similar trend. The Baldt anchor is much more compact for a similar mass, giving it a smaller bearing area and therefore deeper penetration depth, as can be seen in Figure 3-6. In the figure, Baldt anchor and USN/Hall anchor data points are enclosed in orange and blue polygons, respectively.

As discussed in Section 3.1, the surficial sediments across most of the New York Bight can be classified as sands and sandy gravels, making the penetration depths associated with the sand and gravelly sand data points in Figure 3-6 the more likely scenario across the broader region. However, soft sediments are present in certain areas such as New York Harbor, so the depths shown by clay with silt/sand data points could be present depending on the location.

According to the procedures laid out in Section 3.3.1, the more compact Baldt anchor achieves the highest penetration depths, up to an estimated 2.5m (8.2 ft) in clay, 2.1m (6.9 ft) in sand, 1.6m (5.2 ft) in gravelly sand, and 1.2m (3.9 ft) in gravel for a 15,200 kg (33,510 lbm) anchor. The four largest Baldt anchors examined, ranging from 12,500 kg to 20,000 kg (27,558 lbm to 44,092 lbm), appear to level off at approximately the same penetration depths. The maximum penetration depth achieved by a 16,100 kg (35,494 lbm) Hall anchor, a slightly larger mass than the Baldt but larger bearing area, is estimated to penetrate only approximately 1.0m (3.3 ft) in clay and sand, 0.7m (2.3 ft) in gravelly sand, and 0.5m (1.6 ft) in gravel. The five largest USN/Hall anchors examined, ranging from 12,500 kg to 20,000 kg (27,558 lbm to 44,092 lbm), appear to level off at approximately that same penetration depth.

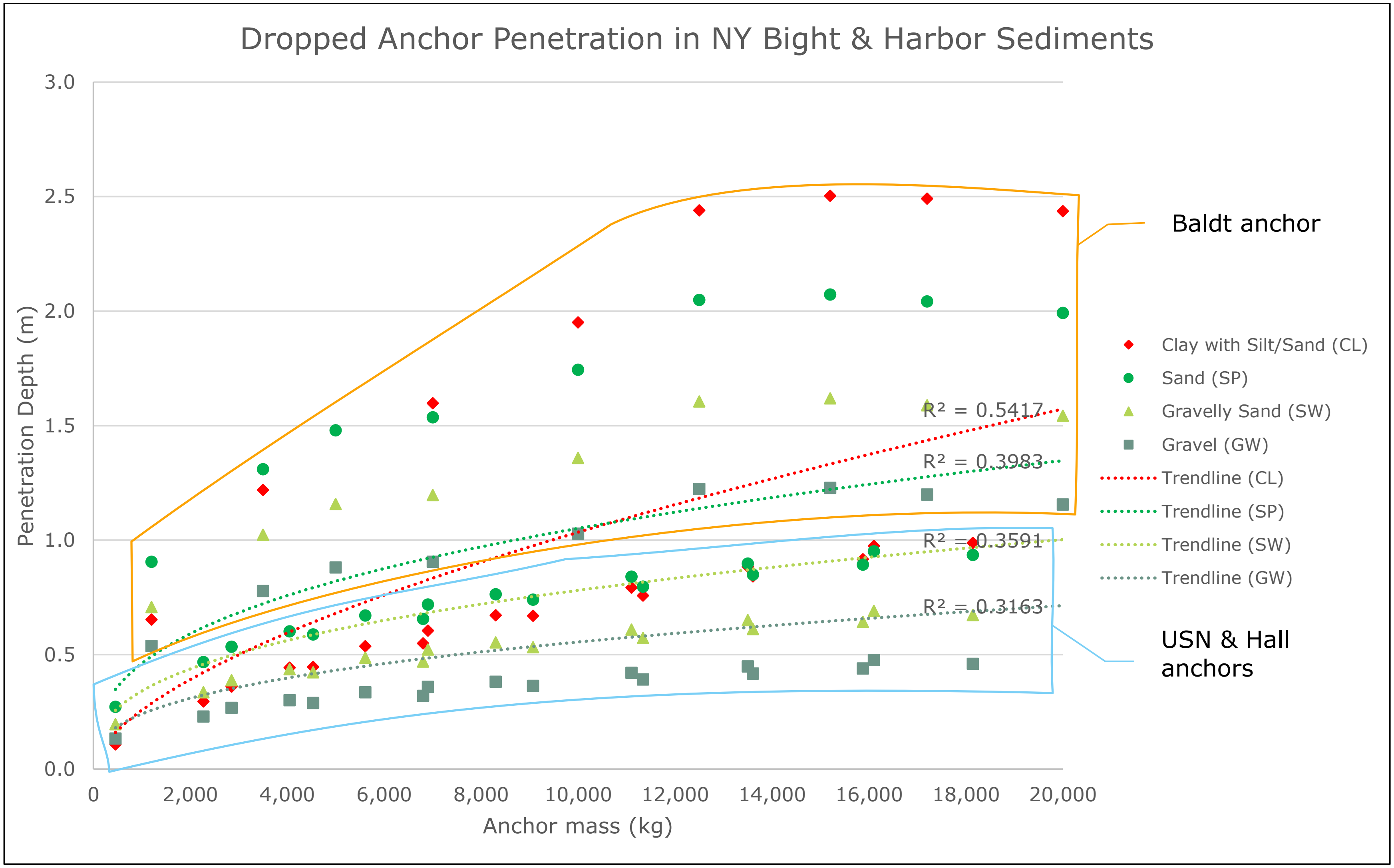

Figure 3-6 – Plot of anchor mass vs. dropped anchor penetration in clay with silt and sand (CL), sand (SP) gravelly sand (SW), and gravel (GW), calculated using the Ref. [47] method.

3.4.2 Dragged Anchor Scenario

Based on the NCEL (Ref. [53]) fluke length-to-penetration depth correlation, drag anchors can be expected to penetrate approximately three times deeper into soft silts and clays than into sands and stiff clays. Most data points generated in this evaluation use this NCEL fluke length-to-penetration depth correlation, so the scatter in data reflects the variation in fluke lengths between the types of stockless anchors (USN, Baldt, and Hall) examined. A graph that plots anchor mass vs. penetration depth in sand/stiff clay and soft silt/clay for the dragged anchor scenario is shown in Figure 3-7.

As discussed in Section 3.1, the surficial sediments across most of the New York Bight can be classified as sands and sandy gravels, making the penetration depths associated with the sand/stiff clay data points and trendline in Figure 3-7 the more likely scenario across the broader region. However, soft sediments are present in certain areas, so the depths shown by soft silt/clay data points could be possible.

In sands and stiff clays, no anchor of a size expected in the study area exceeds 2.9m (9.5 ft) of drag penetration depth. In soft silts and clays, a maximum penetration depth of 9.2m (30.2 ft) could be achieved with a 17,500 kg (38,581 lbm) and 19,500 kg (42,990 lbm) anchor according to the Ref. [1] estimates, assuming the soft layer is that thick and not underlain by a harder layer. Using the Ref. [53] fluke length-to-penetration depth correlation, in soft silts and clays, a maximum penetration depth of 8.4m (27.6 ft) could be achieved with a 12,500 kg (27,558 lbm) anchor (2.8m [9.2 ft] long flukes).

Like in the dropped anchor scenario, there is a visible split between stockless anchor types. The compactness of Baldt anchor extends to its shorter flukes, which results in shallower drag anchor penetration. For example, the 15,200 kg (33,510 lbm) Baldt anchor is only expected to penetrate 4.8m (15.7 ft) into soft silt/clay and 1.6m (5.2 ft) into sand/stiff clay. A USN or Hall anchor of smaller mass, such as a 13,500 kg (29,762 lbm) Hall anchor could penetrate 6.3m (20.7 ft) and 2.1m (6.9 ft), respectively, into those sediments.

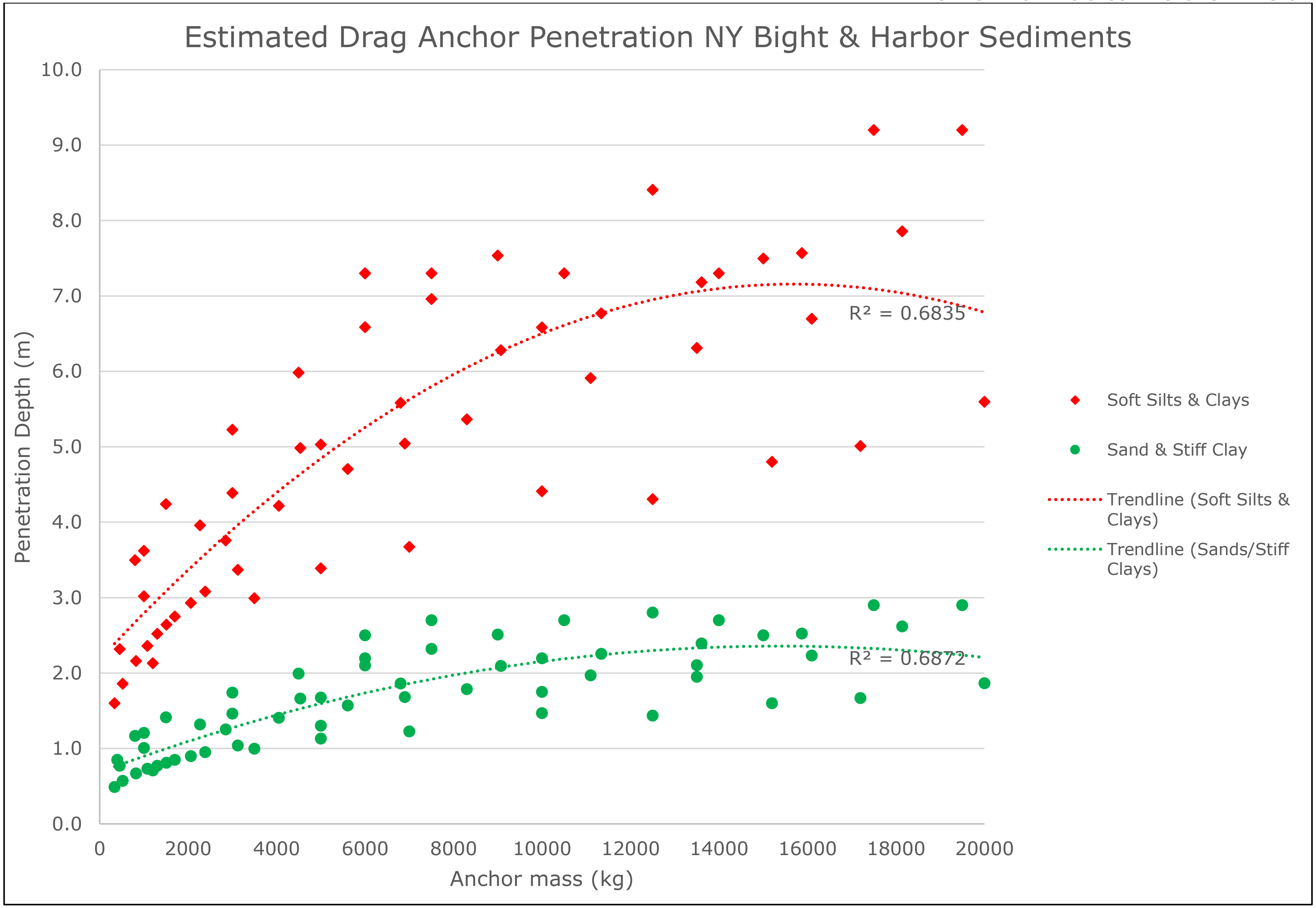

Figure 3-7 – Plot of drag anchor penetration in soft silts & clays and sands & stiff clays based on empirical data and relationships.

4 Discussion and Findings

Significant amounts of submarine infrastructure are installed on or beneath the seabed in the New York Bight and New York Harbor. Additional submarine cables will be installed to connect offshore wind farms to the onshore electric grid in the near future. New York Harbor and its approaches represent some of the busiest waterways in the world, and anchor strikes on existing and future submarine infrastructure have been a key concern of the M-TWG. This report was prepared to inject objective data on anchor strikes and potential anchor penetration into the conversation. This study consists of two tasks: identification of historical known and suspected anchor strikes on submarine infrastructure and an evaluation of methods to estimate anchor penetration.

4.1 Anchor Strikes

In the first task, this study identified and tabulated data on 19 known or suspected anchor strikes on submarine cables and pipelines along the east coast of the United States. In general, publicly available information on anchor strikes is scarce; therefore, this study also relies on the information obtained through outreach to cable owners, operators, and regulators. The tabulated data is provided in Appendix A and detailed case studies on four strikes were presented in Section 2.

Incidents have likely occurred that have not been captured in the Appendix A database because they were not publicly reported. However, the 19 incidents that were uncovered spanned a period of 52 years, suggesting that known incidents are a relatively infrequent occurrence given the number of submarine pipelines and cables present on the seabed and the heavy vessel traffic along the U.S. east coast. Eleven of the nineteen incidents occurred before the year 2000, which could be attributed to strikes being more likely on early cables installed without burial. Modern submarine cable and pipeline burial requirements reduce the likelihood of damage from an anchor strike. Also, early cables were constructed with pressurized dielectric insulating fluid. Modern cables are now constructed with a solid dielectric that, when breached, do not result in fluid release that would trigger regulatory reporting and associated media coverage.

Virtual AIS systems are available and in use at some locations to monitor vessel behavior (i.e. preparing to drop anchor) in the vicinity of cables and alert both the vessel and infrastructure owner/operator. Such systems could be considered for installation at locations where future cables pass through or near areas where vessel crews may be tempted to anchor. Another example measure to consider is Denmark's provision for compensation of lost anchors. When a vessel sacrifices and anchor to avoid damaging a submarine cable or pipeline, the vessel is entitled to compensation for the lost anchoring gear (Ref. [55]).

Based on aggregated data provided by an international telecom cable operator, there have been only two anchor strikes on telecom cables along the U.S. east coast in the last 20 years (Ref. [56]). The type of vessel involved in these incidents was not confirmed to be a commercial cargo vessel or tanker, and their internal database is not necessarily exhaustive. Their data shows that the U.S. experiences far fewer anchor strikes on submarine cables than Europe and Asia (Ref. [57]). One proposed explanation for this is that cables are typically not routed near major vessel transit lanes, ports, and anchorages in the U.S. (Ref. [56]). Based on the aggregated data, strikes from fishing gear appear to be a much more common threat to U.S. submarine infrastructure than commercial vessel anchor strikes (Ref. [56]). The vast majority of global anchor strikes that do occur globally happen in water depths less than 100m (Ref. [58]), which is expected based on the limitations of anchoring equipment carried on vessels.

4.2 Anchor Penetration

The purpose of the anchor penetration task was to investigate the available methods for estimating the depth that a vessel's anchor may penetrate into the seabed, which may then in turn inform stakeholders' perspective on offshore wind cable siting and design. These are theoretical findings, and the ranges of penetration depths estimated by the existing formulas vary significantly and are not sufficiently prescriptive to inform evaluation of appropriate cable burial depth that could be applied on an industry wide basis. This information may be one of many factors considered when evaluating suitable cable burial depths for specific locations, but cable burial requirements should be analyzed on a project-specific basis. Therefore, determination of appropriate cable burial depths is beyond the scope of this study.

This study investigated five (5) analytical methods for estimating dropped anchor penetration and eight (8) methods [five (5) analytical and three (3) empirical] for estimating dragged anchor penetration. Each method considers one or more input parameters such as vessel DWT, anchor mass, anchor fluke length, and/or soil type to estimate penetration depth. Due to the varying input parameters, it is very difficult to make a like-for-like comparison. Methods examined in this study that considered a higher quantity of variables typically provided a more precise estimation of anchor penetration; however, the accuracy of those estimates was not consistently validated against real world data. In most methods, key inputs like the geotechnical properties of the seabed are based on generalized soil descriptions (e.g. "sand", "soft clay", etc.) rather than specific geotechnical properties of the soil (e.g. grain size distribution, unit weight, friction angle, etc.). The types of anchors considered also do not reflect a full inventory of every anchor that may be carried onboard a commercial vessel.

The results presented for dropped anchor penetration represent estimates for four sediment types expected to be found in the study area using generalized soil properties and three stockless anchor types. Dragged anchor penetration sediments are even more generic, since the empirical data and relationships used to develop these estimates provide only broad descriptions of the sediments (e.g. "soft silts and clays" or "sands and stiff clays"). Therefore, the estimates of penetration are less precise than the dropped anchor penetration estimates.

Table 4-1 presents data for three example vessel lengths (LOA) to provide context for the results in a more approachable format than tabulating anchor penetration vs. than anchor size. These chosen LOAs correspond roughly to typical anchor sizes carried onboard vessels of these lengths.

Table 4-1 – High-level summary of estimated dropped and dragged anchor penetration depths in the two most common sediment types in the study area for various vessel lengths.

	Sediment Type	**200m (~650 ft) LOA**	**300m (~980 ft) LOA**	**400m (~1300 ft) LOA**
Dropped Anchor Penetration	Silty/Sandy Clay	0.3m – 1.6m	0.7m – 2.4m	0.9m – 2.5m
	Sand	0.5m – 1.5m	0.7m – 2.0m	0.9m – 2.0m
Dragged Anchor Penetration	Soft Silts & Clays	3.0m – 7.3m	4.3m – 8.4m	5.0m – 9.2m
	Sand & Stiff Clays	1.0m – 2.7m	1.4m – 2.8m	1.7m – 2.9m
Note: Contains aggregated results of methods described herein with consideration of generalized sediment types, common anchor equipment and vessels anticipated and commonly occurring in New York Harbor and the New York Bight.				

Review of available estimation methods supports project-specific cable burial depth evaluation. There is a significant cost differential to the cable owner (more expensive to bury cable deeper). This supports evaluation of cable burial on a location-specific basis, noting that the appropriate cable burial depth may change along a single cable's route.

Anecdotally, a contractor that locates anchors in New York Harbor has observed that most anchors recovered in anchorage areas tend to be embedded within approximately 10 ft below the seabed (Ref. [59]). These anchorage areas are inside of the harbor, where soft mud is the primary surficial sediment. Vessels travel at low speeds in these areas, limiting the horizontal drag distance and force on the anchor, so anchors are unlikely to achieve their full capacity and maximum embedment under normal conditions.

4.3 Opportunities for Future Study

It may be possible to improve the state of the science by conducting additional pull tests. As one potential next step, performing measured anchor pull tests in common anchorage or potential future cable areas would provide valuable information, similar to the tests performed in the German Bight described in the Ref. [2] report. The Ref. [2] report describes a study that deployed vessels with test anchors (8.5 tonne and 11.5 tonne) at selected test sites and used load cells to record pull force, an ROV to record underwater video, and side scan sonar to profile the seabed before and after the drop and drag tests to estimate penetration depth. Results of a local anchor pull test could then be used to calibrate other anchor penetration estimates in the region, especially where similar surficial sediment types are present.

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Appendix A Database of Anchor Strike Incidents

Incident No.	Asset Name	Asset Type	Owner/ Operator	Cable/Pipeline Details	Year Commissioned	Burial Depth	Installation Tool	Sediment Type	Water Depth	Date of Incident	Location of incident
1	**Northport to Norwalk Cable (NNC), historic**	- Electric power cables (qty 7) - 1385 Line Cable System 138kV - 280 MW of power collectively	Long Island Power Authority (maintenance in NY waters only, operated by PSEG) & Conneticuit Light and Power Company (now Eversource also formerly Northeast Utilities)	- 7 separate 3" dia. Fluid filled cables with single hollow core copper conductor with paper insulation, a lead covering, and external armouring. Fluid is dielectric insulator maintained under pressure with dodecylbenzene, also called alkyl benzene or Alkylate 6 (non-toxic and biodegradable) - Newer cables are XLPE 3-phase cables with a solid dielectric - 200ft max depth from shore	- Original cables 1970 - New instsallation 2007 commisioned in 2008	- Original Cables laid on ocean floor (not buried). - New 2007 cable buried 3-10ft typically	- Original cables laid on ocean floor. - New 2007 cable embedded by Northeast Utilities using a Nexans CapJet hydro plow	Typically sand/silt	+/-50ft	Nov 17 2002	- Four (4) locations: (40° 56' 44.7"N, 73° 21' 14.8W") (40° 56' 44.5"N, 73° 21' 6.3W") (40° 56' 44.5"N, 73° 21' 3.8W") (40° 56' 45.2"N, 73° 21' 0.9W") - Approx. a half mile from Northport
2	**Northport to Norwalk Cable (NNC), historic**								13.12ft	July 1969	unknown
3	**Northport to Norwalk Cable (NNC), historic**								55.77ft	Feb 1970	(40° 57' 51.4"N, 73° 21' 15.6W")
4	**Northport to Norwalk Cable (NNC), historic**								65.62ft	Dec 1974	(40° 57' 27.3"N, 73° 23' 42.4W")
5	**Northport to Norwalk Cable (NNC), historic**								39.37ft	Jan 1977	(40° 57' 27.6"N, 73° 21' 32.6W")
6	**Northport to Norwalk Cable (NNC), historic**								39.37ft	June 1977	(40° 57' 30"N, 73° 21' 42.5W") (40° 57' 31.4"N, 73° 21' 35W")
7	**Northport to Norwalk Cable (NNC), historic**								39.37 - 131.23ft	Feb 1979	(40° 57' 53.6"N, 73° 21' 35.0W") (40° 58' 0.07"N, 73° 21' 35.0W") (41° 00' 55.6"N, 73° 22' 38.6W")
8	**Northport to Norwalk Cable (NNC), historic**								38ft	Nov 1989	Lambert Coord. N 261364 E 2181081
9	**Northport to Norwalk Cable (NNC), historic**								50ft	Dec 6, 1996	(40° 56' 56.8"N, 73° 21' 05.6"W) (40° 56' 59.3"N, 73° 20' 58.2"W) (40° 56' 51.5"N, 73° 21' 11.3"W) (40° 56' 58.2"N, 73° 21' 01.0"W) (40° 56' 49.2"N, 73° 21' 13.8"W) (40° 56' 54.5"N, 73° 21' 07.9"W) (40° 56' 30.2"N, 73° 21' 00.8"W) (40° 56' 48.0"N, 73° 21' 17.4"W) (40° 56' 03.3"N, 73° 21' 15.5"W)

Incident No.	Asset Name	Vessel Type	Vessel Size (DWT)	Anchor Type	Extent of Damage	Outcome of Claims/Litigation	Source/ References	Additional Info
1	**Northport to Norwalk Cable (NNC), historic**	Supply vessel & DSV: RMS Citation (formerly Mr. Sonny)	665 tons	- 2-6000lb Aft - 2-7000lb Fwd - 3800ft 1" cable Striking anchor unknown	4 of 7 cables damaged; leaked insulating fluid, officials cut power no power demand issues at the time of incident	- litigation started in Dec. 2002 with LIPA and CL&P pursued the vessel owner and other parties involved in the natural gas pipeline project. Voluntary mediation occured in February 2005, LIPA, CL&P and insurance underwriters reached a settlement agreement with vessel owner and other parties, completed in April 2005. - Application of LIPA for certificate of environmental Compatibility settlement agreement Aug. 2008 - 1385 cable to be drained, cut, capped and abandoned for sections LIPA are unable to remove and conduct a monitoring program spanning 10 years for benthic biology and bathymetric monitoring. LIPA to request the abandoned cables be noted on appropriate NOAA maps.	[1],[14],[16],[17],[18],[19],[20],[21],[22],[19], [9] Frank Bertrand	- Northport, NY to Norwalk, CT power cables; anchor drag during storm 0.5 miles from Northport; vessel being used to construct 36-mile natural gas pipeline on Iroquois Gas Transmission System pipeline project from Northport to the Bronx; LIPA jurisdiction for investigation - Replacement project $140M, No reported anchor incidents after 2007
2	**Northport to Norwalk Cable (NNC), historic**	Dredge barge			Cable 7 damaged		[9] Frank Bertrand, PSEG	
3	**Northport to Norwalk Cable (NNC), historic**	Oil tanker			Cable 7 damaged		[9] Frank Bertrand, PSEG	
4	**Northport to Norwalk Cable (NNC), historic**	Repair barge			Cable 7 damaged, half capacity for 9 months as a result		[9] Frank Bertrand, PSEG	
5	**Northport to Norwalk Cable (NNC), historic**	Buoy anchor			Cable 4 damaged; repaired 27 of March 1977		[9] Frank Bertrand, PSEG	Due to buoy anchor and ice floe
6	**Northport to Norwalk Cable (NNC), historic**	Storm repair barge anchor			Cable 3 & 4 damaged; half capacity for 6.5 months		[9] Frank Bertrand, PSEG	
7	**Northport to Norwalk Cable (NNC), historic**	Buoy anchor			Cable 1, 4, and 7 damaged		[9] Frank Bertrand, PSEG	Due to buoy anchor and ice floe
8	**Northport to Norwalk Cable (NNC), historic**				Anchor drag severed cable 5		[9] Frank Bertrand, PSEG	Temp clamp 11/28-fault
9	**Northport to Norwalk Cable (NNC), historic**	Oil tanker			- Cable 3, 5, and 7 severed and 1, 2, 4, and 6 damaged and leaking by run away oil tanker dragged anchors - leakabaters, adams clamps used in repairs		[9] Frank Bertrand, PSEG	

Incident No.	Asset Name	Asset Type	Owner/ Operator	Cable/Pipeline Details	Year Commissioned	Burial Depth	Installation Tool	Sediment Type	Water Depth	Date of Incident	Location of incident
10	**Long Island Sound Transmission Cable Y-49**	Electric power cable 345 kV with average load of 600 MW	New York Power Authority owned and maintained by LIPA as primary user	4 independent fluid filled 3-phase cables (three phases and a spare) Cable operates with dielectric fluid, DCL 45, at 160psi	1991	10 ft average approx. 600ft apart			100 ft	- Feb 2003 [21] - 2004 [3]	
11	**Long Island Sound Transmission Cable Y-49**	Electric power cable 345 kV with average load of 600 MW	New York Power Authority	4 independent fluid filled 3-phase cables (three phases and a spare) Cable operates with dielectric fluid, DCL 45, at 160psi	1991	10 ft average approx. 600ft apart			100ft (35ft at damage location)	Jan 6, 2014	(40°52'17.39"N, 73°40'44.10"W) Estimated based on map overlay with firgure from ref. [29]
12	**CVOW demonstration project export cable**	Electric power cable	Dominion Energy Coastal Virginia Offshore Wind (CVOW)			2m (target) [10ft]					
13	**Central Hudson Gas and Electric PK (Poughkeepsie Kingston) pipeline**	Natural gas pipeline	Central Hudson Gas and Electric	- PK line - 8" dia. distribution pipeline from Poughkeepsie Recieval Station west across Hudson River to just north of the Poughkeepsie railroad bridgeand north along west shore to Kingston Holder Station with max. allow operating pressure (MAOP) of 60psi - TP line - transmission pipeline from Tuxedo to Poughkeepsie with 2-8" parallel pipeline with MAOP 565psi	1931	Unknown; no regulations requiring burial at time of installation	- line laid directly across bottom of river, no trenching - river crossing 3125ft shore to shore - 1983 dive survey found pipeline had significant amounts of exposure (480ft) and suspension (110ft) on PK line and TP line with at least 4 feet above the bottom in some areas. Survey warned a line suspended (undercut) above the river bottom may be subject to damage by drifting debris and ships' anchors. HR/DR and ZTP lines were protected with rock and Central Hudson did not protect PK line at all.		approx. 50-60ft	Aug 8, 1999 approx. 09:04am	Hudson River near Poughkeepsie, NY near Poughkeepsie Railroad Bridge

Incident No.	Asset Name	Vessel Type	Vessel Size (DWT)	Anchor Type	Extent of Damage	Outcome of Claims/Litigation	Source/ References	Additional Info
10	**Long Island Sound Transmission Cable Y-49**	Gulf Horizon vessel (alleged)	- Summer DWT 1494 t - Horizon Group was aqcuired by Boskalis, this vessel has since been scrapped in India		- 1 cable of 4 damaged casuing a fault, leaking insulating fluid 2 gallons/hr over 6000 gallons lost, decided power cut to all cables. Temporary repairs included capping cables, conducted within 10 days. Permanent repairs complete Sept. 2003. $35M USD in repairs and clean up - repairs included cable lay vessel to splice in replacement section	- Litigation arising from the incident started Aug. 2003. LIPA and NYPA and its property damamge insurer engaged in litigation against barge owner and other parties involved in the gas pipeline project. NYPA and LIPA collectively filed claims in the limitation action asserting total damages of approximately $21-25 million. - Magistrate Judge Johnson Mem. & Rec, 3-cv-3280 (S.D. Tex.), Dkt. 302; Venezia Ex. B13 at 3.	[2],[21],[3],[23],[25],[28]	- Cable crosses New Rochelle, NY to Hempstead Bay (North to South) - Barge being used in nearby Iroquios Gas Transmission System pipeline project constructing 36-mile natural gas pipeline from Northport, Long Island to the Hunts Point, NY. - Cable onshore has been reportedly unreliable for more than 6 months (April 2021), subsea portion is ok
11	**Long Island Sound Transmission Cable Y-49**	Tug boat Ellen S. Bouchard operated by Bouchard Transportation Co. filed for bankruptcy Sept. 2020	Summer 1000 t	6,000 lb anchor	- 1 cable damaged (C phase Cable No. 3) causing a fault; leaking insulating fluid at 50 gallons/hr at peak approx. 6,600 gallons, officials cut power. Anchor penetrated seabed by 10ft impacting cable - $35M USD in repairs and clean up repairs included cable lay vessel to splice in replacement section 200ft long	- Power Authority of the State of New York v. M/V ELLEN S. BOUCHARD, and the BARGE B No. 280 - NYPA claims damamges of $22,168,509.69 and LIPA claims damages of $2,717,048, the amount awarded is unknown	[3], [4], [5], [15],[27],[28],[29], [31],[32],[33]	-Cable crosses New Rochelle, NY to Hempstead Bay (North to South) - Barge dropped anchor in Hempstead Harbor; previously damaged in 2004. - After this event in 2016 NYPA did trials with Vesper Marine for a virtual AIS protection system. - Cable onshore has been reportedly unreliable for more than 6 months (April 2021), subsea portion is ok
12	**CVOW demonstration project export cable**						[6]	**Indicates a repair program, no specific indication that the damage is a result of an anchor strike.**
13	**Central Hudson Gas and Electric PK (Poughkeepsie Kingston) pipeline**	Tug Scott Turecamo and barge Maria T	Scott Turecamo - 166 net tonnage Maria T - 8865 net tonnage	4500 lb fluked anchor	- Maria T dragging anchor while undertow (pushed) of Scott Turecamo southbound approx. 6knots speed - Severed 8" dia. PK line Natural gas pipeline causing gas to escape. TP river crossing suffered minor abrasion damage, and minor rock cover damage over HR and DR electrical lines. Immediately Central Hudson closed valves on both sides of the river for PK and TP lines. - Waterway was closed for approx. 4 hours after incident. - TP line repair by applying new exposy coating to damaged pipe	- Central Hudson Gas Electric Corp. vs. tug Scott Turecamo, barge Maria T, LaFarge Bulding Materials Inc. and Moran Towing Corp. Action was tried soley on issue of damages. Cetnral Hudson sustained damages of $648,487.75 but are also comparatively negligent assigned 25% responsibilty for the damage. Central Hudson is entitled $486,365.81 plus prejudgement interest (3.73%). - Value of natural gas lost $8,439 - Rock cover replaced at $6,700	[7],[35],[36],[37]	- Central Hudson pursued the most cost effective option to abandon the PK river crossing and install a regulator station (called west shore regulator station) on the west shore of the Hudson River. A short length of PK line south end was cut and connected to north end of TP line on west shore. - During construction of station, the PK Line was tested for contamination with environmentally-toxic polychlorinated biphenyls (PCBs) revealing elevated levels of PCBs in the PK Line. In the spring of 2000, Central Hudson engaged divers to cut back sections of the river crossing and cap the line to avoid further leakage. - PK line has been cut, capped and abandoned - Full coast guard incident report avail. in refs

Incident No.	Asset Name	Asset Type	Owner/ Operator	Cable/Pipeline Details	Year Commissioned	Burial Depth	Installation Tool	Sediment Type	Water Depth	Date of Incident	Location of incident
14	**Sound Cable**	- 7 Electric power cables run from the LILCO powerplant in Hicksville - New York across the bottom of Long Island Sound to Connecticut; each can carry 138 kV of electricity	- LILCO own operate and maintain all of the Cable within the State of New York - CL&PI own operate and maintain all of the Cable within the State of Connecticut	4" dia fluid filled (DCL 45) with hollow copper core with paper wrapping followed by lead and armoring including plastic covers,a hemp layer, and braided aluminium cable wrapping in a plastic coating.	1987?					- Dec 6, 1996 - Winds from north at 25knots air temp 38degF, heavy rain	broke loose mooring at LILCO, Northport Platform, 2.4 nautical miles east of Eaton's Neck Point, offshore of Northport, Long Island, New York
15	**Cable 91, 97, or 75 (cables landing at West Chop)**	Electric power cable serving Martha's Vineyard	Eversource	Each cable transmits 23kV load						July 16, 2021	
16	**Unknown - Electric power cables supplying power to Martha's Vineyard**	Electric power cables	Commonwealth Electric Company							April 5, 1980	Approx. 600 feet west of a marked cable crossing
17	**Unknown SubCom database**	Single armor cable	unknown	Single armor cable, repair of segment No. 3 cable type FS=SL100 SA (FS=final splice, SA = single armor)	unknown	unknown	unknown		105ft (32m)	Date of fault notification (may not be the fault/incident date) August 6, 2009	LatDD 27.5; LonDD -80.08

Incident No.	Asset Name	Vessel Type	Vessel Size (DWT)	Anchor Type	Extent of Damage	Outcome of Claims/Litigation	Source/ References	Additional Info
14	**Sound Cable**	Barge T/B Texas	28103 t		- T/B Texas broke loose from mooring after unloading fuel at LILCO Northport Platform, the attending tug Heide Moran failed to control, Texas dropped it's anchor to maintain position. 4 of 7 cables damaged, 2 completely severed; 5000 gallons dodecylbenzene (DCL 45) coolant fluid released. - Approx. 5,700 gallons were lost by December 11, that day 2 of the cables were capped by divers reducing flow from 20 gallons/hr to about 2 gallons/hr. - Cables inoperable from Dec. 6 1996 to Jun. 27, 1997 threatening "voltage collapse" in SW Conneticuit - Duration of response was about two weeks to install temporary clamps and leak abaters - Repair costs $17.8M USD ($15M covered by insurance) permanent repairs completed June 1997	CL P paid $11,420,000 to repair the cables and $5,072,278 in emergency expenditures to prevent the risk of a voltage collapse in south west Connecticut	[8],[38],[39],[40],[41]	The cables are used to transfer power between Connecticut and Long Island during peak-usage, usually summer, to make up any shortfalls due to energy consumption.
15	**Cable 91, 97, or 75 (cables landing at West Chop)**				1 of 4 cables damaged; 2,250 people lost power; Repairs by barge expected to take 2-4 weeks		[11],[12],[48]	**No indication that the cable was damaged by marine activity such as a boat. Damaged line has been sent to lab for analysis to confirm. The results of the analysis were not discovered by this study.**
16	**Unknown - Electric power cables supplying power to Martha's Vineyard**	Passenger ferry - Naushon operated by Woods Hole, Martha's Vineyard and Nantucket Steamship Authority, Out of service as of 1987	2,652 gross tonnage	3450 lb stockless Navy-type anchor	- Ferry had boiler feed-pump emergency lost power and dropped starboard anchor dragging it into the cable crossing cuting power to Vineyard. - The damage did not occur at the point of anchor drop/drag, they only showed signs of recent disturbance (turned over and twisted. - The actual breaks occured at a distance resulting from strain on the cables being dragged.	Awarded damages of $552,125 plus interest to Commonwealth Electric Company	[13],[49],[53]	Ferry lost propulsion and dropped anchor, dragging a considerable distance; once propulsion was restored, weighed anchor and immediately all power supplied by these cables to Martha's Vineyard went off.
17	**Unknown SubCom database**	unknown	unknown	unknown	unknown fault	unknown	[56] & Atlantic Cable Maintenance Agreement, slide 8	**The fault type is unknown, it is not confirmed that this fault is a result of an anchor strike.** **Repair vessel Pacific Guardian**

Incident No.	Asset Name	Asset Type	Owner/ Operator	Cable/Pipeline Details	Year Commissioned	Burial Depth	Installation Tool	Sediment Type	Water Depth	Date of Incident	Location of incident
18	**Unknown SubCom database**	LWP/FBP/SPA = Light Weight Protected/Fish Bite Protected/Special Purpose Application 15-19mm cable.	unknown	LWP/FBP/SPA 15-19mm cable.	1998 - 2000 installed	Likely <3.3ft (1m) based on years installed	unknown		223ft (68m)	28 Nov. 2003	LatDD 40.22; LonDD -71.98
19	**Unknown SubCom database**	Double armor >19mm diameter	unknown	Double armor >19mm diameter	1998 - 2000 installed	Likely <3.3ft (1m) based on years installed	unknown		217ft (66m)	28 Nov. 2003	LatDD 40.23; LonDD -71.95

Incident No.	Asset Name	Vessel Type	Vessel Size (DWT)	Anchor Type	Extent of Damage	Outcome of Claims/Litigation	Source/ References	Additional Info
18	**Unknown SubCom database**	unknown	unknown	Listed as anchor strike, anchor and vessel type unknown	unknown fault	unknown	[56] & International Cable Protection Committee, slide 10	Repair vessel Maersk Responder Based on their locations it is not conclusive what type of ship caused the fault. This occured at the same time as another fault on an adjacent cable making it likely that the same vessel or fishing boat may have caused both. The cables were installed in 1998 and 2000 and burial depth was likely to be approximately one meter or less.
19	**Unknown SubCom database**	unknown	unknown	Listed as potential anchor strike, anchor and vessel type unknown	Cable full tension break. Fault possibly caused by anchor.	unknown	[56] & International Cable Protection Committee, slide 11	Repair vessel Atlantic Guardian and buried by ROV Based on their locations it is not conclusive what type of ship caused the fault. This occured at the same time as another fault on an adjacent cable making it likely that the same vessel or fishing boat may have caused both. The cables were installed in 1998 and 2000 and burial depth was likely to be approximately one meter or less.