

Reconciling Conflicting Utility Location Data: A Case Study of Submarine Gas Lines in the Providence River

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Abstract

During the course of a major harbor dredging project it was learned that three ten-inch diameter, high-pressure gas lines traversing the Federal Channel may not have been buried to the proper depths. After researching the plans of record on the subject gas line, the USACOE found that the originally permitted burial depths of the pipeline conflicted significantly with two more recent electronic surveys that had been performed. Several more surveys using electronic methods of locating the pipes were attempted; however, because of site constrictions and the pipeline configuration, functionally repeatable results could not be obtained.

Because electronic surveys had not produced consistent results, the owner and the USACOE turned to the most reliable method – that of unearthing portions of the pipe, however the Channel depths, the pipe cover and port traffic made this a formidable task. The following case study documents how this task was accomplished.

Introduction

The U.S. Corps of Engineers (USACOE) was in the process of performing improvement dredging of the Federal Channel in the Providence River to a design depth of –41' Mean Lower Low Water (MLLW), plus two feet of allowable overdepth. The channel design had taken into account the permitted burial depth of three ten-inch diameter steel gas pipelines that crossed the river. The original permits for the pipelines indicated that they had been buried to a depth of –50 feet MLLW, which would have provided adequate coverage under the DOT regulations. During the course of the dredging project it was learned that the actual records of the pipeline installation (in 1954) were fragmented – and in fact there were no realistic as-built surveys of the pipes. After considerable study, the USACOE determined that the originally permitted burial depths of the pipeline conflicted significantly with two more recent "electronic location" surveys, which were performed by the pipeline's owner. Because of the disparity between these surveys, and the fact that recent surveys showed the pipelines to be significantly shallower in depth than the permits allowed, the USACOE determined that the survey data of record was too ambiguous to be relied on, and as such it could not dredge much of the 150 foot wide corridor directly over the pipeline route. This area became known as the “no-dredge” zone and it extended 415 feet into the Federal Channel from the Western channel limit, and 305 feet into the Federal from the Eastern channel limit. Pursuant to this issue, the USACOE sent a directive to the pipeline owner to provide a functionally accurate, certified survey of the pipeline, and if the pipeline was found to be out of compliance with permits, to correct or remove same. The directive required physically locating and identifying each of the three pipes in a number of locations, surveying each pipe’s position at these locations, and then having a Registered Professional Engineer certify that the surveyed locations were correct. Because of the conflicting record data, electronic and/or sonic methods of pipeline location were not considered acceptable means of survey.

The Utility owner contacted the engineering and surveying services firm (CLE Engineering, Inc.) who was already working on site for possible solutions to this directive. This engineering firm was requested to develop and conduct a survey that would satisfy the USACOE’s requirements. This assignment was problematic because it required that the pipes be uncovered in a number of locations, at water depths exceeding 55 feet and because the issue occurred at the time of the winter heating season, the pipelines could not be de-pressurized for more than a short time during the investigation. This meant that the pipes had to be uncovered and measured for depth while “live” and in use which required that a number of safety related issues be addressed. Also, because the pipeline owner was concerned about the long-term life of the pipe, an excavation methodology needed to be devised that would guard the pipe and coating against any possible damage during the excavation process.

Methodology

Attempts to Locate the Pipes by Electronic Methods

The history of electronic pipe location attempts began in 1995 when the pipeline owner contracted with a diving company to perform a survey using a combination of electronic sounding and conventional hand probes. This party produced a plan and profile of the pipeline crossing, however because of a significant error in the vertical datum applied; the pipe appeared much deeper on the profile than it actually was. Since there were no plans for dredging of the river on the horizon at that time, the utility owner did not have any reason to look for a problem and the drawing was simply placed in the file. During that same time period, another company performed an electronic pigging survey of the pipe’s interior, however the pig’s electronics were limited and the pig only recorded pipe interior condition, length and approximate location of bends, thus it was of little help identifying the pipe’s physical location. It was not until the beginning of the dredge project in 2003 that anyone had reason to look more closely at the 1995 survey.

As part of an area study relating to a concurrent dredging project, it was requested that the utility owner provide copies of any plans and/or surveys of the pipe. When these plans and the 1995 survey were reviewed it became apparent that there was an obvious datum error on the later survey. Further, when an approximated correction was applied, it placed significant portions of the pipeline within the dredging template. The USACOE was notified of the problem, and in turn they classified the suspect areas as a "no dredge zone" until the problem could be resolved. This prompted the need for follow-up surveys to attempt confirmation of the pipeline burial depth. The Utility owner re-contracted the same diving company to return and re-survey the pipeline, this time under the observation of the USACOE. The diving company employed essentially the same methods as they had used in the 1995 survey, however this time using better tidal correction data. The resultant profile was completed and when the profiles were compared, they showed essentially the same burial depths as the (corrected) original survey. The Utility owner's engineering firm was then contracted to locate a more sophisticated electronic location system to survey the pipeline. However, the search became problematic, in that the configuration of the pipeline valve pits, and several abrupt bends in the pipeline crossing prohibited the use of more accurate "tracking" pigs (due to the length of the pig). The search however did lead to one company, the specialized in Pipeline Tracking Systems, who had a technology whereby the pipes were isolated electrically, and then a "loop wire" was added across the waterway, connecting the extreme ends of the underwater crossing. Thereafter a signal generator was connected to produce an electro-magnetic field on the pipeline. The signal was then traced by running a survey boat back and forth across the pipeline at 20 to 50 foot offsets, recording bottom depth, pipeline horizontal position and pipeline burial depth. The system data was calibrated by physically probing and locating the pipe in a few known locations where the pipe burial was minimal. The survey resulted in a pipeline plan and profile that again differed considerably from earlier surveys. The most dramatic difference was found in the pipe alignment, whereby the new electronic survey showed the pipe's alignment bowed approximately 50 feet to the south of the "straight" alignment shown on both the as-built trench plan as well as the diver surveys. The new electronic survey also showed the estimated pipeline depth profile to be very close to the original trench survey (albeit somewhat different in several critical locations) and considerably different than the diver surveys of 1995 and 2004.

Nonetheless, there remained a number of unresolved disparities between the various plans and surveys. There was the (1) original Permit Plan, (2) the informal trench survey by the original installation contractor, (3) the 1995 diver survey, (4) the 2004 diver survey and (5) the 2004 Electronic survey. Even though the 2004 Electronic survey appeared to be the most accurate and reliable of all, the USACOE, in concurrence with the Utility's Engineering Firm agreed that because of the potential risk to public safety, some form of physical confirmation survey should also be performed to assure all parties of the actual pipe location. It was also determined that no dredging would be done within 75 feet of the pipeline corridor until the location was physically confirmed.

General Description

There was much concern on the part of all involved parties that any unearthing of the pipelines in the marine environment would cause damage or leaks in an area where they would be very difficult to repair. In response to this concern, a plan was developed to carefully unearth each pipeline and physically locate it with a reasonably high degree of accuracy. The methodology, proposed in the permit applications to the USACOE, Rhode Island Coastal Resources Management Council (CRMC), and the Rhode Island Department of Environmental Management (DEM) was modified slightly in the field as existing conditions dictated. In general the following procedures were followed:

The plan was to remove silt and clay materials overlaying the pipeline in selected various locations and the pipe was to be identified and then physically surveyed at these locations. Proper surveys conducted under these conditions would determine the precise vertical and horizontal position within 0.5-foot tolerance vertically and under three feet horizontally. The pipeline was to be exposed in a number of locations within the Federal Channel as well as both the East and West U.S. and RI Harborlines, dependent on field conditions such as the presence of rip rap or unstable side slopes.

The process of physically uncovering the pipes was one of the biggest challenges. There was a high degree of concern by all parties that the pipelines not be damaged in the process of uncovering them. Unfortunately, this precluded most of the common, more productive methods of marine excavation. Methods that utilized clamshell buckets or cutterhead-suction devices were ruled out. Because of the large disparity between surveys the depth of excavation could range from as little as six feet, to as much as eighteen feet below the existing harbor bottom. Water depths also made the process difficult, as the areas of the most critical verification surveys depths ranged from 34 to 40 feet, with the addition of as much as five feet of tide. It was determined that the most viable and safe method to uncover the marine sediment and clay from over the pipes was to use a marine "airlift".

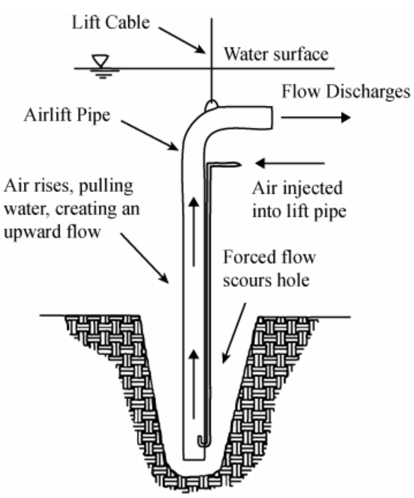

Fig. 1 Simplified diagram of how airlift works.

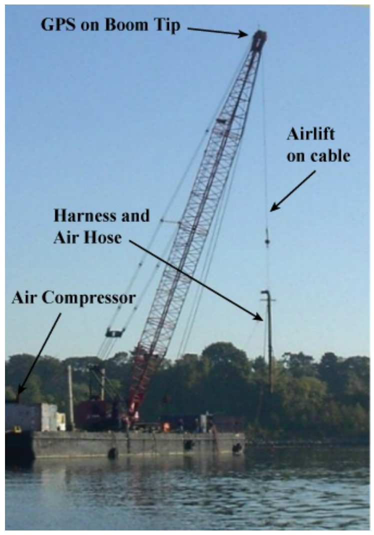

Fig. 2 Airlift suspended from cable, preparing to be lowered into water to begin excavation.

An airlift is a dredging tool that works by injecting compressed air through a small diameter pipe (2") at the bottom of larger diameter pipe (12"). The air is injected into the bottom of the larger pipe that is positioned vertically on the river bottom by use of a cable suspended from a barge-mounted crane. The advantage of the airlift is unique in that it has the ability to scour and remove marine sediments without the need for hard digging devices, such as clamshell buckets. Instead, the air injected at the bottom of the airlift pipe rapidly rises up to the top of the pipe and the bubbles of the air stream and create a forced upward flow of water and air within the pipe. The airlift utilizes the velocity of the combined flow to agitate and liquefy marine soils, and literally suction them up the pipe and away from the area of intended excavation. Accidental abrasive damage to the pipe and coating system was prevented by the use of a rubber shoe fastened to the bottom of the airlift. Like a giant underwater vacuum cleaner, the airlift gently removed the soils overlying the pipes until they were exposed. This same technology is often used for underwater excavation of delicate archeological sites.

There were 21-targeted areas where the pipe was to be located. At each location an area of exploration was targeted; as each hole was excavated, a diver would enter the hole to attempt physical location of the pipe. Because clouds of suspended sediment remained in the excavation, diver visibility was non-existent once the diver entered the hole. From that point on all pipe location inspections were strictly done by feel. Unfortunately, the marine soils covering the pipes varied considerably in consistency, ranging from gelatinous muck to moderately stiff marine clay. This caused a large variety of excavation formations, each of which had to be individually verified for stability progressively as the diver entered the excavation. Only professional divers, with backgrounds in what are known as “black water” penetrations, with surface supplied air, emergency air and radio communication were employed.

Detailed Work Sequence

The work platform was a 40’ by 160’ barge equipped with a Model 4100 Manitowoc crane, plus two 1,300 cubic feet per minute (CFM) air compressors, with three outfitted cabins to serve as all weather enclosures for men and equipment. There were facilities for diver operations, electronic position monitoring, and equipment storage.

Barge and Airlift Positioning

The engineering firm was tasked with the responsibility of providing positioning for both the barge and airlifting operations. Both functions were critical to the investigation effort, the first system being required to properly position the barge in relation to the alignment of the pipeline, and the second system to accurately position the airlift over projected pipe locations.

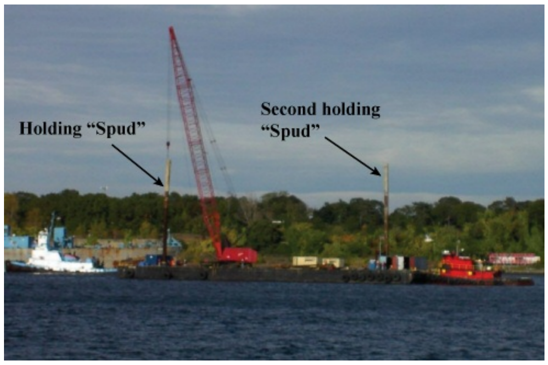

Fig. 3 Crane barge being pushed into position adjacent to pipeline.
Note: Crane is about to lower and "set" one of two holding spuds.

The method determined to be the most reliable for holding the barge in place during airlifting was the use of spuds, which consisted of two large 30" diameter pipes. Spuds were determined to have an advantage as they had far less tendency to slip or drag such as anchors might, and they confined barge movement (drifting) to a few feet while on station. The negative feature required setting the spuds near the exact limits of the designated "no-spud" zone, which was 75 feet from the anticipated center of the pipeline corridor. This was complicated because it was learned that there was not only a disparity in the pipe's depth, but there was also a significant disparity in where the pipes laid with respect to its permitted alignment. (One of the earlier electronic surveys showed the pipes bowing as much as 50 feet off line to the south of the previously designated corridor.) As such, the position of the pipeline in relation to the no-spud zone changed as the work approached the center of the river, to a point where it was within a few feet of the southerly "no spud" limit, which in turn made barge positioning extremely critical in these areas. The positioning system for the barge was a "Vector" antenna (heading accuracy to ½ degree and submeter positioning) integrated with a hydrographic graphic and coordinate display software package. This was necessary in order to identify the position of both spuds in relation to the "no-spud" zone before they were set into the bottom. The airlift positioning system was a single antenna GPS with sub-meter accuracy. The boom tip GPS also served a second function, acting as a redundant system to confirm the position of a spud before it was set. Barge and airlift positioning systems were monitored by a Field Engineer using a tracking computer with two monitors. Each showing the anticipated pipeline locations, the barge position and alignment, as well as the airlift position, all in real time. One monitor was located at the computer station, and a second monitor was located in the cab of the crane. Prior to the start of work, the entire system was calibrated against known control, including the existing pipeline valve boxes. During the progress of the project the location of each test excavation was logged and the location of the hole was recorded on the screen.

As a precautionary measure, during the initial exploratory phase of the investigation the pipeline Utility Owner opted to shut off the flow of gas through the pipelines to allow testing of the work and safety plans. Because neither the horizontal location nor depth of the pipes were known with any degree of surety, it was determined to start exploration in shallow water on the East side of the river, where the pipe was known to have only a few feet of cover. This plan served two purposes, it allowed for relatively quick test pit excavation to obtain projected pipe depth, and the shallow water allowed for better visibility, making identification and inspection of the pipe easier. Conversely, soil conditions in this area turned out to be relatively stiff marine clays, which made uncovering the pipes slow and difficult. The underwater slope characteristic of the soils in this area left the sidewalls of the excavation at a very steep slope. As such, while the initial penetration hole of the airlift took only a short time, it took a considerable amount of time for that airlift to widen the hole to a size where the diver could safely enter the hole. Because of these difficult soils the initial contact with the first pipe required the excavation of numerous "dry" holes, and took almost two days to accomplish. Once the pipes were finally found, and upon removal of the overburden from above the pipelines in the shallow trench, a diver equipped with a video camera entered the excavation and confirmed a pipeline had been located. In order to confirm the find, and determine if the diver was on the north, middle or south pipeline, personnel were positioned in the closest manhole that could provide land access to the pipes. The diver then "sounded" the pipe by tapping on the metal surface allowing the shore personnel to listen on each pipe for the tapping, then to report back to the barge. The diver then held a survey rod on the top of the pipe that extended above the water surface. The prism at the top of the survey rod was located by both land and water based surveys on shore utilizing a theodolite and electronic distance meter, a method that would provide the most accurate and reliable position data. The elevation of the top of the pipe relative to MLLW and its location relative to the Rhode Island State Plane coordinate system was then determined. A secondary redundant verification method was also used, wherein the location of the pipe was noted by the airlift positioning system and its depth was noted relative to the water surface elevation as read from the survey rod while it was held on the pipe.

Once an accurate position of each pipe was ascertained, it was possible to project each individually known pipe alignment ahead a few hundred feet to the next area of exploration, so as to reduce the search area for the next station. For the locations of the pipelines in deeper water it became necessary to locate a point on the cable suspending the airlift that was a known distance from the bottom of the airlift, then to place the air lift directly over the pipeline and shoot a hand held prism held on the mark with land based survey equipment. The secondary method used the distance from the known point to the water surface as measured by the water based surveyors from their survey boat, and the GPS location of the airlift.

Operations within the Federal Channel were more restricted than work outside of the channel, in that freight traffic navigating the channel had to be considered. At the end of each day's work, in consideration of maritime safety, the barge had to be moved from its working position, and relocated to a place near the edge of the channel out of the way of shipping. In addition, the excavation areas had to be surveyed at the end of each day, to ensure that any shoals crated by the airlifting did not protrude above the published navigation depth, where they could create a grounding hazard. Hydrographic surveys were also conducted during the excavation process to document the river bottom topography and to note the conditions before and after airlifting. This data was also collected to provide defense against potential shoaling claims from the dredging contractor.

Upon completion of the final pipeline location on November 2, 2004 the Contractor backfilled the open test pits that remained over the pipelines in the shallow areas.

Observations

The results of the pipeline survey were graphically presented on a plan prepared the Owner's Engineer. Field Engineers were on board the barge each day to position the barge and airlift as well as log the daily operations. Professional Hydrographic Surveyors also performed daily hydrographic surveys and provided supply and transportation between the barge and the shore. Copies of the daily survey data in the form of fathometer rolls and raw survey data were archived for future reference.

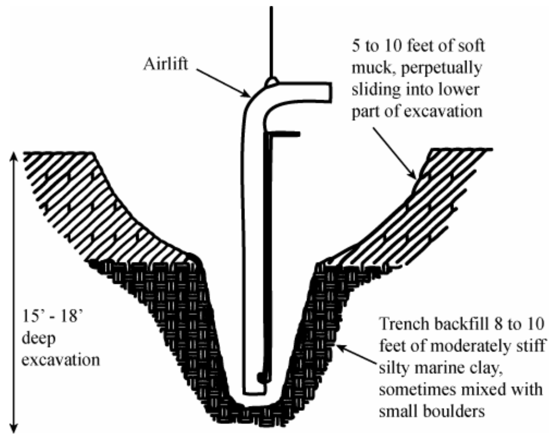

Fig. 4 Typical Air lifted exploration hole

In General most of the exploratory holes developed the funnel shape shown in the above figure. Soils on the Western limit of the channel were found to be considerably softer, and were unstable to deeper depths than the Eastern two thirds of the channel. The only way to overcome the instability was time-consuming, and involved the process of greatly enlarging the upper portion of the excavation. In other locations the stratification of the marine soils overlying the pipes caused a number of problems, including a persistent sloughing of the soft muck in the upper surface layers into the smaller lower excavation. At times a second soft layer was found near the pipeline depth, which tended to create a "bell hole" at the bottom of the excavation. This condition could only be stabilized by "punching" numerous holes through the intermediate stiff layer until it collapsed on itself, thereby opening the excavation to a width where it was safe for a diver to enter the excavation.

The pipeline inspection revealed a number of noteworthy conditions that differed significantly from prior documentation of record.

- In general the pipes were found to be at or close to the design grade of –50 feet MLLW, except in two locations. About 85 feet of pipe was found to be above the design grade on the Eastern shore, the shallowest pipe depth was at –44.7 feet below MLLW, or about 5.3 feet above the minimum permitted depth, in addition 25’ of this section was above the elevation required to allow the minimum four feet of cover required for excavation of the new channel depth. Because of this encroachment, the Eastern 100’ of the Federal channel was not dredged for the 150 foot length of the “no-spud” zone. On the Western limit of the Federal Channel about 95 feet of pipe was also found to be above grade, the shallowest pipe was found to be –49.7 feet below MLLW, or about 0.3 feet above the minimum permitted depth. This condition did not encroach on the minimum four-foot cover requirement, and thus did not affect the Federal dredging.

- In general, the 2004 electronic survey proved to be most accurate of the electronic location methods. In the western “no dredge” zone the actual pipeline depth was found to be approximately 1.5’ to 3’ higher than indicated by the 2004 Electronic Survey, which was close to the advertised vertical accuracy of ±2’.
- The 2004 Electronic horizontal position survey proved extremely valuable in locating the pipe and it proved to be the most accurate with respect to preceding methods, especially with respect to predicting the actual “bowed” alignment of the pipes. Further, because of the large disparity between the permitted pipe alignment and the actual alignment, if the 2004 Electronic alignment survey had not been available for initial guidance, pipeline location operations would have required considerably more time.
- While traces of gravel were found from time to time in the pipeline excavation, in no instance was the presence of measurable quantities of gravel backfill in the pipeline trench. (Gravel bedding and cover had been indicated on various plans and documents of record that were reviewed prior to the pipeline excavation.)
- The backfill material over the pipelines in the east side of the Federal Channel was found to be a moderately stiff marine silt and clay that held almost vertical side slopes. Conversely, the backfill material over the pipelines on the extreme West side of the Federal Channel was much softer (almost soupy), as such it would not hold reliable side slopes; this required that excavations be much larger. Concentrations of 12” boulders were found in a number of locations on the Western exploration area, which also made excavation more difficult. Not only did the boulders tend to lodge in and clog the air lift, but their presence made hand probing by the divers much more difficult.
- There was no evidence of typical marine coating on any of the pipes, such as heavy taping or concrete jacketing, nor was there any evidence of the cast iron jackets referred to in permit documents. Oak staves or strapping of unknown length, measuring roughly 2” by 2” were found along the long axis of a few of the pipelines in a few of the Eastern locations. The original intended purpose of this wood is not known.
- Two wooden piles were found protruding from the bottom in the vicinity of the first pipe excavation. It is assumed that these piles were either range markers or devices originally used to hold the pipes on line while they were being pulled across the river.
- The pipes were found to be out of compliance with respect to the 10-foot separation shown on permit drawings. The middle pipe was found to encroach on the

southern pipe, and in fact was laying directly on top of the southern pipe for a significant percentage of the route. It is possible that the middle pipe actually crosses over the South pipe somewhere on the eastern third of the channel, then re-crosses back over the South pipe about 500 feet east of the Federal channel limit.

- The pipelines were found to be south of their design locations by as much as 50'. Based on projections it could be as close as 20' to the southerly limit of the Federally designated "No Spud Zone".

The figures below show typical trench conditions that were anticipated from documentation of record, versus what was actually found from field exploration.

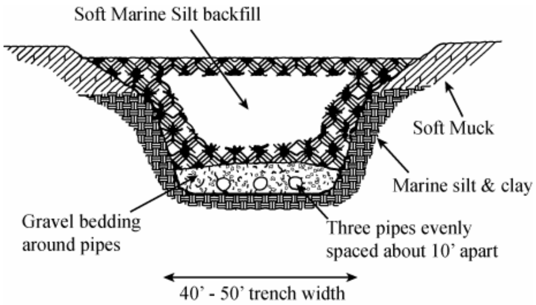

Fig. 5 Expected pipe placement and burial conditions based on documentation.

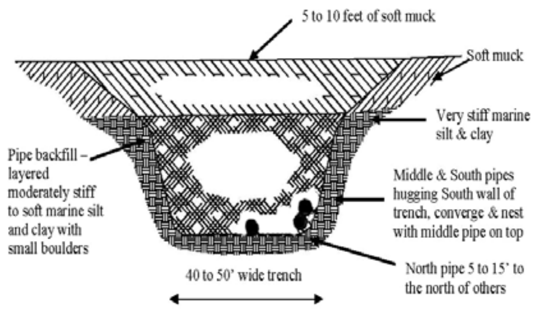

Fig. 6 Typical pipe trench conditions found during investigation.

Conclusions

Based on the results of the gas pipeline survey of October 2004, it was determined that the gas pipelines in the Western "no dredge" zone, were found to be much deeper than the earlier electronic surveys, yet still above the minimum design depth at several critical locations. The survey also indicated the gas pipelines had been placed well off of the planned alignment, which not only made them more difficult to locate, but nearly placed them in an unprotected dredge zone. The most non-compliant area was the Eastern most section of the pipe within the Federal channel. The shallowest pipe depth in this area was above the elevation required to allow the DOT's minimum four feet of cover required for excavation of the new channel depth. Because of this encroachment, the dredging of the Eastern 100' of the Federal channel was delayed until a safe method for its excavation could be worked out and approved. Ultimately the USACOE cleared the channel to the design depth with the provision that the interfering pipes ultimately be replaced or abandoned within the next few years.

In summary, this study emphasizes the importance of thorough and accurate survey, as well as careful documentation of underwater utilities placed in navigation channels. It also shows that one cannot always rely of older, uncertified plans of record, especially when inconsistencies are found. The impact of not doing so on this project was a delay in completion of the channel of at least four months, and a cost to the utility company of almost two million dollars.