Intergovernmental Oceanographic Commission of UNESCO

Oman National Multi Hasard Early Waning System

Technical Visit to Oman to Assess Locations
For Future Tide Gauges

November 5th to the 17th 2010

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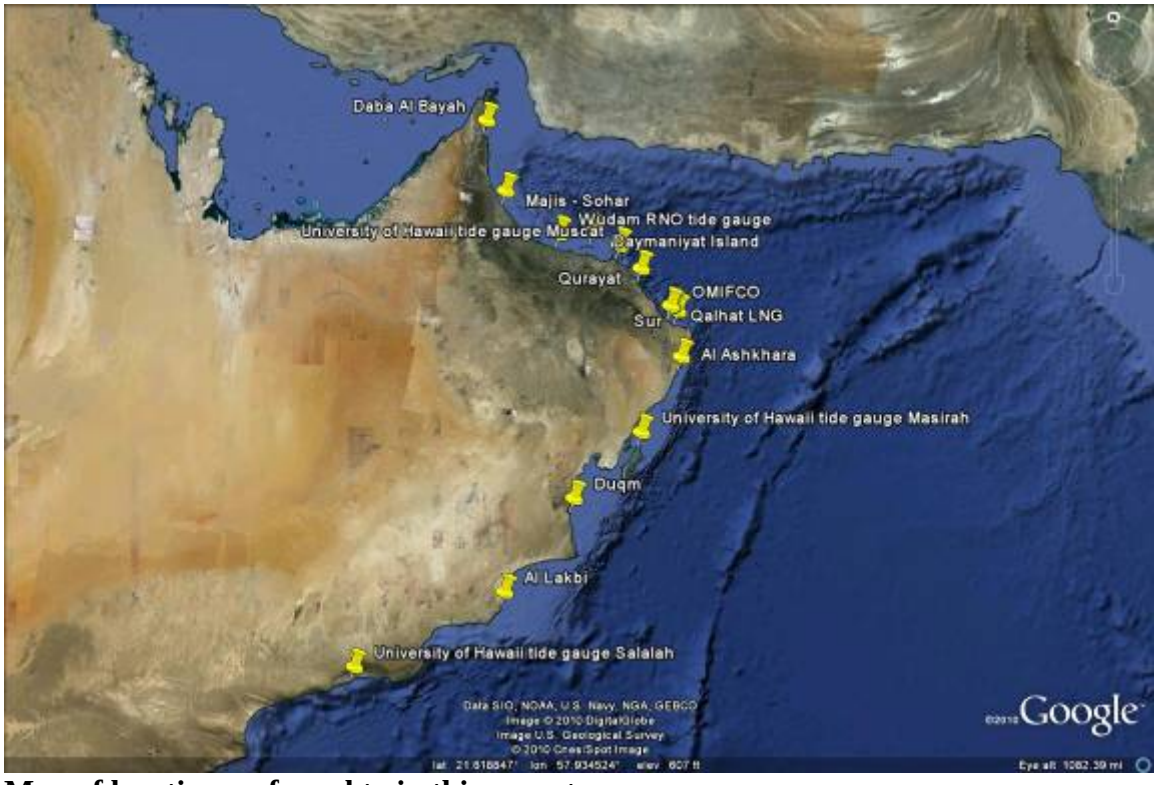
Objectives:
Under the Oman-UNESCO agreement concerning development of the Oman National Multi Hasard early Waning System (NMHWS) IOC organised a technical mission to Oman to visit and evaluate a number of potential sea level monitoring sites. to evaluate the potential for tide gauge equipment at each site, and to provide specific recommendations regarding the best location to install the equipment at each site. Various criteria including water depth, security and site access, satellite sky view, existing tide gauge and meteorological equipment, benchmark networks, mobile phone network signal strength and electrical service were reviewed.

The mission was carried out in cooperation with the Directorate General of Meteorology and Air Navigation (DGMAN),

The original list of sites to be visited was (i) Daba Al Bayah, (ii) Majis, (iii) Wudam, (iv) Qurayat, (v) one among Qalhat or Omifco Plant Harbor or Sur, (vi) Al Ashkhara and (vii) Al Lakbi. Subsequently Duqm was substituted for Al Lakbi and the Daymaniyat Islands were added.

The University of Hawaii has operated tide gauges in Muscat. Masirah and Salalah for a number of years. A brief description of these tide gauges is included with this report.



Map of locations referred to in this report

Executive Summary

Summary of recommendations:

Location	Overall recommendation	Minimum civil works needed
Al Ashkhara	Yes, but shallow	None
Al Lakbi	Not without major construction	Freestanding concrete platform in the sea
Daba Al Baya	Maybe, but with limited sensors and some damage risk	Vertical steel guard posts after tide gauge installed
Daymaniyat Islands	Maybe, but difficult	Concrete block base on rocks
Duqm Port	Yes, but after major construction is completed	Vertical steel guard posts after tide gauge installed
OMIFCO	No	Not applicable
Qalhat	No	Not applicable
Qurayat	Yes, but shallow	Vertical steel guard posts after tide gauge installed
Sohar (Majis)	Yes	Vertical steel guard posts after tide gauge installed
Sur	Yes	Vertical steel guard posts after tide gauge installed
Wudam	Yes	None

Al Ashkhara Fisheries Port, Oman
The location at Al Ashkhara is a good place for a modern satellite transmitting tide gauge. The water depth at the proposed location is shallower than ideal, but meets the minimum requirement generally used.

Al Lakbi Fisheries Port, Oman
Should it be necessary to install a complete modern tide gauge at Al Lakbi, a freestanding concrete platform built to support a tide gauge would be needed.

Daba (Dibba) Al Baya Fisheries Port, Oman
Short of constructing a freestanding concrete platform or a significant protective structure on the dock face, which would interfere with the normal functions of the port, it is not practical to build a tide gauge with an ideal mix of tsunami and long term sea level monitoring sensors here. A tide gauge focused more on tsunami detection would be practical, though there would be a chance of accidental damage to the equipment.

Daymaniyat Islands, Oman
While it would be possible to install tide gauge equipment at the Daymaniyat islands, it would be a difficult job. Security for the tide gauge equipment would be a concern, maintenance visits would be difficult, and the water is only marginally deep enough. Unless there is a compelling reason to collect tide gauge data from these islands instead of on the main coast of Oman, it is not recommend.

Duqm Port, Oman
The port of Duqm appears to have a good location for a modern satellite transmitting tide gauge. At this point with major construction still underway, it is too early to

install equipment. It is however, probably a good time to discuss the installation with the port management so accommodation for a tide gauge can be made if needed.

Oman India Fertilizer Company (OMIFCO) Plant, Oman
While it may be possible, attempting installation of a tide gauge system at this location is not recommended. The administrative and technical challenges of installing equipment here would be significant.

Qalhat Liquid Natural Gas Plant, Oman
Attempting to install a tide gauge system at this location is not recommended. If data is needed from this site, investigating how to access the data already being collected by the facilities own sensors and systems would be a better choice.

Qurayat (Qurayyat) Fisheries Port, Oman
The location at Qurayat is a good place for a modern satellite transmitting tide gauge. The water depth at the proposed location is shallower then ideal but meets the minimum requirement generally used.

Sohar (Majis) Port, Oman
All standard components of a tide gauge could be easily installed at two different locations identified in this report. The two sites have potential sky view issues depending on the satellite used and future construction planned at the port.

Sur Fisheries Port, Oman
The location at Sur is a good place for a modern satellite transmitting tide gauge, however it is important to determine first what construction is planned for the area immediately behind the proposed tide gauge site in case it conflicts with using the area for a tide gauge.

Wudam Port, Oman
The location at Wudam is a fine place for a modern satellite transmitting tide gauge.

Schedule:
November 2010:
4th: Arrived in Oman
6th: Inspected Daba Al Baya
7th: Inspected Majis (Sohar)
8th: Inspected Wudam & meeting with Dr. Al Harthy at DGMAN
9th: Inspected Qurayat & Qalhat & OMIFCO
10th: Inspected Sur & Al Ashkhara
11th: Serviced Masirah tide gauge
12th: Inspected Duqm
13th: Traveled back to Muscat from Duqm
15th: Inspected Daymaniyat Island
17th: Departed Oman

Coordinates of Locations referred to in this report:

Location name	Longitude	Latitude
Al Ashkhara suggested location	59.5732126949	21.8569202504
Al Lakbi	56.5490374408	18.1837234578
Daba Al Bayah suggested location by fisheries souk	56.2690835773	25.6498297397
Daba Al Bayah suggested location by petrol station	56.2690815126	25.6502421720
Daymaniyat Island suggested location	58.1062000000	23.8571000000
Duqm suggested location	57.7248000000	19.6637000000
Majis - Sohar suggested location option A	56.6259990286	24.4938333383
Majis - Sohar suggested location option B	56.6069158798	24.5188862599
OMIFCO suggested location	59.4358857769	22.6505825796
Qalhat LNG existing tide sensor location	59.4137664829	22.6641629394
Qurayat suggested location	58.9251342257	23.2602589899
Sur suggested location	59.5288449779	22.5778510981
Masirah tide gauge operated by University of Hawaii	58.8707633664	20.6869899034
Muscat tide gauge operated by University of Hawaii	58.5653225018	23.6275821436
Salalah tide gauge operated by University of Hawaii	54.0073542717	16.9353907996
Wudam RNO tide gauge	57.5265321278	23.8255027692

Solar and satellite sky views considered:
During the site surveys, the sky-view of each site was reviewed for potential obstructions to solar panels and for antenna orientation towards particular satellites. The satellites considered are listed and their approximate orientations for Oman are listed below.

METEOSAT 6 (backup) & 7 (operational) both at approximately 170º from true north and 64º elevation above the horizon.

METEOSAT 9 at approximately 257º from true north and 21º elevation above the horizon.
INMARSAT BGAN I-4 EMEA at approximately 240º from true north and 45º elevation above the horizon.

External references and thanks:

Photos:
Full resolution versions of the photos are enclosed on a DVD.

Tidal predictions and Z_0 information obtained from:
Oman Maritime Book (2010)
Oman National Hydrographic Office
Royal Navy of Oman

Acknowledgments:
A special thanks to Dr. Al Harthy of the Directorate General of Meteorology and Air Navigation, Oman, for arranging all the details of transportation, access passes, and scheduling within Oman, and to Engineers Ahmed Al Rashdi and Said Al Harthy for driving all across Oman and back!

Al Ashkhara Fisheries Port, Oman

Inspected November 10, 2010. Measurements and photos taken at 12:00 PM local time. Tidal state at time of measurements and photos according to predictions: approximately 2.3 m above chart datum. Z_0: 1.73 m above chart datum.

Main point of contact interviewed at port:
Mr. Salim Al-Rasbi, Al Ashkhara Port Director, mobile +968 993 35 860

General port description:
Al Ashkhara is a small fisheries port in the small town of Al Ashkhara about a 3-hour drive from Muscat. There is a port office inside the port gate. During the inspection, there was very little activity at the port. Mr. Al-Rasbi stated port activity is low from October to February but then increases substantially for the rest of the year due to the fishing season in that area. Mr. Al-Rasbi was not aware of any previous tide gauge equipment. According to Mr. Al-Rasbi the port was constructed in about 2004. The Oman Ministry of Fisheries Wealth has a web site describing the Al Ashkhara port here: http://www.mofw.gov.om/english/tabid/420/Default.aspx.

Meteorological and other related sensors and systems:
No meteorological or other sensors were observed.

Potential for tide gauge equipment:
There is a potentially good location for a tide gauge at this port on the northeast corner of the back side of the main concrete jetty running east to west. This is the only section of the concrete walled jetty that appears to be out of the way of most boat operations. The best spot on this wall is the far seaward end of the jetty wall just past the last of 3 black and yellow concrete blocks on this side of the jetty (see figures 1 and 2). See the appendix for additional photos. This spot was chosen for the maximum water depth on this section of wall. The area has a concrete deck and a vertical concrete wall, which extends down from the deck about 3 m. The distance between the deck and the water at the time of the photo was approximately 192 cm and the depth of the water at the time of measurement was about 5.5 m. Siltation could become an issue at this dock and at all the fisheries ports examined but it appears that dredging of these ports is done as needed. According to Mr. Al-Rasbi, the port currently had a problem with a sand berm near the entrance preventing boat traffic at low tide, but that dredging was planned soon. All standard components of a tide gauge could be easily installed here.

Figure 1

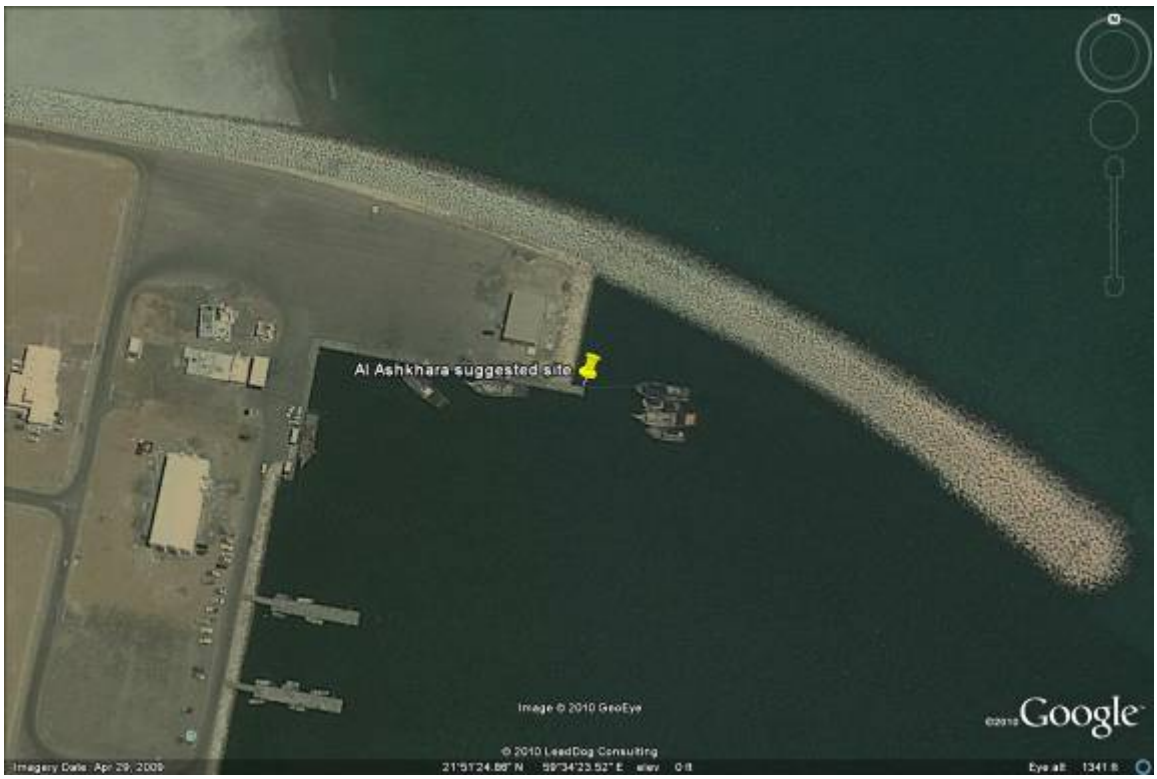


Figure 2

Security:
The port is open to the public 24 hours every day. It is monitored part-time by a security guard. Despite the lack of controlled access, the threat to tide gauge equipment from theft or vandalism here, and in most of Oman, seems small. Mr. Al-Rasbi expressed concern that children playing at the port could damage the tide gauge equipment by climbing on it.

Solar and satellite sky view:
The sky view for all the satellites considered in this report and for solar photovoltaic panels at the proposed location was unobstructed.

Mobile phone signal:
Oman Tel: 5 bars
Nawras Tel: 5 bars

Electrical service:
Electrical service should be possible with some concrete trenching.

Benchmark networks:
No benchmark networks were found and Mr. Al-Rasbi was not aware of specific benchmarks in the port.

Conclusion:
The location at Al Ashkhara is a good place for a modern satellite-transmitting tide gauge. The water depth at the proposed location is a little shallower than ideal, but meets the minimum requirement generally used.

Al Lakbi Fisheries Port, Oman

During this inspection trip, it was decided that an inspection of Duqm port would replace Al Lakbi Port, so Al Lakbi Port was not visited.

The satellite view of the port provided by Google Earth (see figure 3 below) was inspected and people who live near and are familiar with the port were questioned by telephone. It was confirmed that Al Lakbi does not have any hard concrete jetties. Due to this, short of installing a freestanding concrete platform to support a tide gauge, Al Lakbi does not have any suitable locations for installing tide gauge equipment.

Figure 3

Should it be necessary to install a tide gauge at Al Lakbi, a design similar to the example below (see figure 4) would probably be appropriate. This example of a freestanding concrete platform built to support a tide gauge was installed in June 2010 at Lubang Island, Philippines.

Figure 4

Daba (Dibba) Al Baya Fisheries Port, Oman

Inspected November 6, 2010. Measurements and photos taken at 2:30 PM local time. Tidal state at time of measurements and photos according to predictions: approximately 0.35 m above chart datum. Z_0: 1.80 m above chart datum.

Main point of contact interviewed at port:
Mr. Tarik Bin Ali Shihi, Chief of development section, mobile +968 992 30 828

General port description:
Daba Al Baya is a small fisheries port about a 5 hour drive from Muscat. Although Daba Al Baya is within Oman, it is necessary to drive through a thin section of the United Arab Emirates on the way from Muscat to reach there. It was described as quite busy. During this inspection, it was moderately crowded. According to Mr. Bin Ali Shihi, by nightfall there would be many more boats. There is a police office and some small police boats. There are also diving and tourist boat operations. There is limited vertical concrete dock space and floating docks on both sides of the port. Mr. Bin Ali Shihi said the port was built in the mid 1980's. Mr. Bin Ali Shihi was not aware of any previous tide gauge equipment. The Oman Ministry of Fisheries Wealth has a web site describing the Dibba Al Baya port here: http://www.mofw.gov.om/english/tabid/414/Default.aspx.

Meteorological and other related sensors and systems:
There is a set of meteorological sensors installed on the roof of a building inside the port (see photo in appendix). According to Mr. Bin Al Shihi, the equipment was installed in about 2005 under the Oman Ministry of Municipality.

Potential for tide gauge equipment:
There was no ideal location for tide gauge equipment. Two potential sites were reviewed, each with limitations (see figures 5, 6 and 7):

1 – Front of fishery souk
This site would take advantage of one of the vertical notches in the pier face currently supporting a steel ladder. Sensors could be placed on the pier wall behind the ladder. A shallow trench in the concrete, leading from the notch back about 2 meters to a mast assembly supporting the electronics, would be required. This location would only be safe for below-board sensors such as pressure, bubbler, or reference level switches. A tide staff would be possible, but reading the staff would require standing on a boat or climbing down the ladder. No radar or float sensor is practical without significant construction to protect it, which would affect the functions of the port. The mast assembly would require fencing or vertical steel guard posts in the concrete around it to protect it from accidental damage by trucks, boat lines and other traffic. Mr. Bin Al Shihi said one of the davit arms used for loading and unloading boats could potentially be removed to make a safer spot for a mast assembly. Siltation could become an issue at this dock and at all the fisheries ports examined, but it appears dredging of these ports is done as needed. Dredging operations were underway at this port during the visit.

2- Adjacent to Al Maha petrol station
This site is essentially the same as the first site, using another of the vertical notches in the pier face currently supporting a steel ladder. However, this site is adjacent to the port's Al Maha petrol station and offers more protection for the mast assembly by

virtue of the protections afforded the petrol pumps. Mr. Bin Al Shihi was doubtful permission could be obtained from the petrol company to put the equipment here.

Figure 5

Figure 6

Figure 7

Security:
The port is open to the public from 6 AM until 12 PM and there is a police office inside the port. It appears the threat to tide gauge equipment from theft or vandalism here, and in most of Oman, is small.

Solar and satellite sky view:
The sky view for all the satellites considered in this report and for solar photovoltaic panels at the proposed location was unobstructed.

Mobile phone signal:
Oman Tel: 5 bars
Nawras Tel: no signal

Electrical service:
Possible with minor concrete trenching.

Benchmark networks:
No benchmark networks were found, and Mr. Bin Al Shihi was not aware of any benchmarks in the port.

Conclusion:
Short of constructing a freestanding concrete platform inside the harbor or a significant protective structure on the dock face, which would interfere with the normal functions of the port, it is not practical to build a tide gauge with an ideal mix of tsunami and long-term sea level monitoring sensors here. A tide gauge focused more on tsunami detection would be practical, though there would be a chance of accidental damage to the equipment since both potential sites are in the center of port activity. See the appendix for additional photos of the port area.

Daymaniyat Islands, Oman

Inspected November 13, 2010. Measurements and photos taken at 11:00 AM local time. No tidal predictions for the Daymaniyat islands were available. Prediction for Port Sultan Qaboos 55 km to the southeast at time of measurements and photos was approximately 1.8 m above chart datum. Z_0: 1.93 m above chart datum.

Main point of contact interviewed:
There was no one available to interview for this report. The Daymaniyat islands are uninhabited except for a couple of security or conservation personnel, who were not present during the inspection.

General description:
The Daymaniyat islands are located about 20 km north of Seeb, Oman. They are a small group of nine low-lying islands running east to west. The area is considered a nature reserve and is renowned as a recreational diving site. The main island has a few small buildings to accommodate the security or conservation personnel. There are no piers or other man-made structures in the water, so only a beach landing is possible by boat. Most of the shoreline is rocky and appears to be volcanic in origin. Only a few sites are suitable for landing a small boat. During this inspection trip, there were several recreational dive boats with divers. Several web sites list the islands as a UNESCO World Heritage Site, though there appears to be no mention of it on the official UNESCO World Heritage Site.

Meteorological and other related sensors and systems:
No meteorological or other sensors were observed.

Potential for tide gauge equipment:
Because these islands have no man-made structures in the water, the only option, short of building a freestanding concrete platform in the sea to support a tide gauge, is to build on the rocky shoreline. We circled a few of the islands for inspection, but focused on the main island, where there are good beach landings, and where the buildings and personnel are located. We also focused on the south side of the island facing the coast of Oman since it is more protected from most storms. By snorkeling the coast, a relatively deep spot next to the rocky shore was found (see figures 8, 9 and 10). Most of the area is too shallow, but this spot is about 1.5 meters deeper than the surrounding area. The deep spot adjacent to the shore is only about 2 m in diameter but it begins less then 50 cm from the shore. The water depth at the time of measurement was 2.87 m. Based on predictions from Mina Qaboos, the water depth here at lowest low tide would be about 1 m. This is only marginally deep enough for a tide gauge, especially during storms. The rocky shoreline was about 2 m above the water at time of measurement. This is not high enough above the sea to protect the tide gauge equipment, so a concrete platform would need to be constructed on top of the rocks. A block about 1 meter square and 1.5 meters high directly on top of the rocks and encompassing the seaward edge of the rocks is recommended. This would raise the base of the tide gauge equipment to about 3.5 m above mean tide and provide a vertical wall for mounting in-water equipment. Once this was completed, a standard tide gauge could be installed. Installation would be complicated by the remote location, requiring everything to be brought to the island by small boats and unloaded from the beach. Even going empty-handed to the selected site over the rocks is a tricky several-minute walk from the beach. Installation could also only be practically accomplished with relatively calm seas and good weather.

Figure 8

Figure 9

Figure 10

Security:
During this visit, there did not appear to be any official personnel on the island. In fact, we were the only people ashore. While there may be regulations regarding access to the islands, there appeared to be no one to enforce them. Because the area appears at least sometimes completely without supervision, moderate concern about the safety of tide gauge equipment from theft or vandalism is prudent.

Access:
According to this web site, http://www.al-hakawati.net/english/Civilizations/oman5.asp, it is strictly forbidden to visit the Daymaniyat Islands from May to October due to bird breeding grounds. Conservation concerns may also be a factor complicating permission to install equipment here.

Solar and satellite sky view:
The sky view for all the satellites considered in this report and for solar photovoltaic panels is unobstructed. .

Electrical service:
There is no electricity on the island.

Benchmark networks:
No benchmark networks were observed.

Conclusion:
While it would be possible to install tide gauge equipment at the Daymaniyat islands, it would be a difficult job. Security for the tide gauge equipment would be a concern, maintenance visits would be difficult, and the water is only marginally deep enough. Unless there is a compelling reason to collect tide gauge data from these islands instead of on the main coast of Oman, it is not recommend.

Duqm Port, Oman

Inspected November 12, 2010. Measurements and photos taken at 3:00 PM local time. Tidal predictions for Duqm were not available.

Main point of contact interviewed at port:
Due to the weekend, it was not possible to interview any port officials.

General port description:
Duqm Port, currently still under construction, will be a major industrial port and dry dock. It is located outside the town of Duqm, currently a small town but soon to be expanded significantly. Duqm is about a 6-hour drive from Muscat. A new airport for Duqm is also currently underway. A description of the port project from the Oman News Agency can be found here: http://www.omannews.gov.om/ona/english/report4.jsp.

Meteorological and other related sensors and systems:
No meteorological or other sensors were observed at the port. Certainly meteorological and marine sensors are or will be a part of the port's operations.

Potential for tide gauge equipment:
Since the port is still under construction, it is not possible to determine the best location for tide gauge equipment. A potentially good location was selected based on the drawings, as well as an inspection of what appears to be a completed section of the dock. This spot is on the south side of the eastern-most dock (site A). It looks as though this area will be away from ship operations and will probably have a clear sky view. This site is still under construction. It was not possible to access this spot directly due to construction works. It was possible to inspect and measure an adjacent section of the dock (site B), which looks as though it will be identical in design to the selected spot (See figures 11 and 12). The reason for selecting site A over B, despite their identical design, is that the orientation of site B may result in sky view obstructions to METEOSAT 9 when ships are docked adjacent to it, while site A should remain unobstructed. Site B has a concrete deck and vertical concrete wall extending down about 2 m. The distance from the deck to the water at the time of measurement was 325 cm. The depth of the water at the time of measurement was 460 cm. It appears this area will be deeper once some construction rubble is removed. It looks as though all standard components of a tide gauge could be easily installed here. Two vertical steel posts should be installed as guards against vehicles bumping the equipment after its installation. Although site A looks as through it will be out of the way of port operations, it was not possible to determine this with certainty.

Figure 11

Figure 12

Security:
During this visit, using an official vehicle from the Ministry of Transport and Communications and traveling with representatives from this ministry was sufficient to gain access to the port area. Certainly once the port is completed, security will be fully implemented and the area will be closed to the public.

Solar and satellite sky view:
The sky view for all the satellites considered in this report and for solar photovoltaic panels at site A look like they will be unobstructed.

Mobile phone signal:
Oman Tel: 5 bars
Nawras Tel: 2 bars

Electrical service:
Electrical service should be possible, especially if arranged for before construction of the port is completed.

Benchmark networks:
No benchmark networks were observed.

Conclusion:
The port of Duqm appears to have a good location for a modern satellite-transmitting tide gauge. At this point, with major construction still underway, it is too soon to install equipment. It is however, probably a good time to discuss the installation with the port management so that accommodation for a tide gauge can be made if needed.

Oman India Fertilizer Company (OMIFCO) Plant, Oman

Visited November 9, 2010. Photos taken at approximately 3:00 PM local time.

Main point of contact interviewed at plant:
Mr. Said M. Khalfan Al saadi, Safety Officer, OMIFCO (see business card in appendix).

General port description:
The Oman India Fertilizer Company (OMIFCO) Plant in Oman is a major industrial facility used for the production and loading of urea and ammonia onto cargo ships. It is located near the town of Sur about a 3-hour drive from Muscat. The project was built at a total cost of US$ 960 million and commenced operation in 2005 (from OMIFCO web site). See the OMIFCO web site for additional details: http://www.omifco.com/.

Meteorological and other related sensors and systems:
The OMIFCO facility operates two meteorological stations onshore. One reason meteorological information is monitored here is in case of an ammonia leak, so that the direction the gas travels can be predicted. Mr. Khalfan Al saadi was not aware of any tide gauge sensors installed at the facility.

Potential for tide gauge equipment:
The OMIFCO facility is not a good place for the installation of a tide gauge system. The facility is highly engineered and any new equipment would require specific engineering for its installation, especially on the jetty itself. This is particularly due to the hazardous nature of ammonia, which is transferred in pipes to the end of the jetty for loading. The jetty is also very tall to accommodate the large ships it services and is not protected by a breakwater from open sea. Both these factors would further add to the challenge of installing a tide gauge system.

The only area identified as sufficiently out of the way of ship operations and with a good sky view is quite near the pipes carrying ammonia. Access to this area would require climbing over these pipes or arranging for the construction of a catwalk over them. Safety around these pipes is very important consideration. In addition, any work outside safety railings of the jetty would come under scrutiny by the OMIFCO safety department. That being said, only a tide gauge system using an open-air radar sensor would be possible at the suggested location (see figures 13 and 14). In-water sensors would be very difficult due to the height of the pier above water, estimated at 15 m or more.

Figure 13

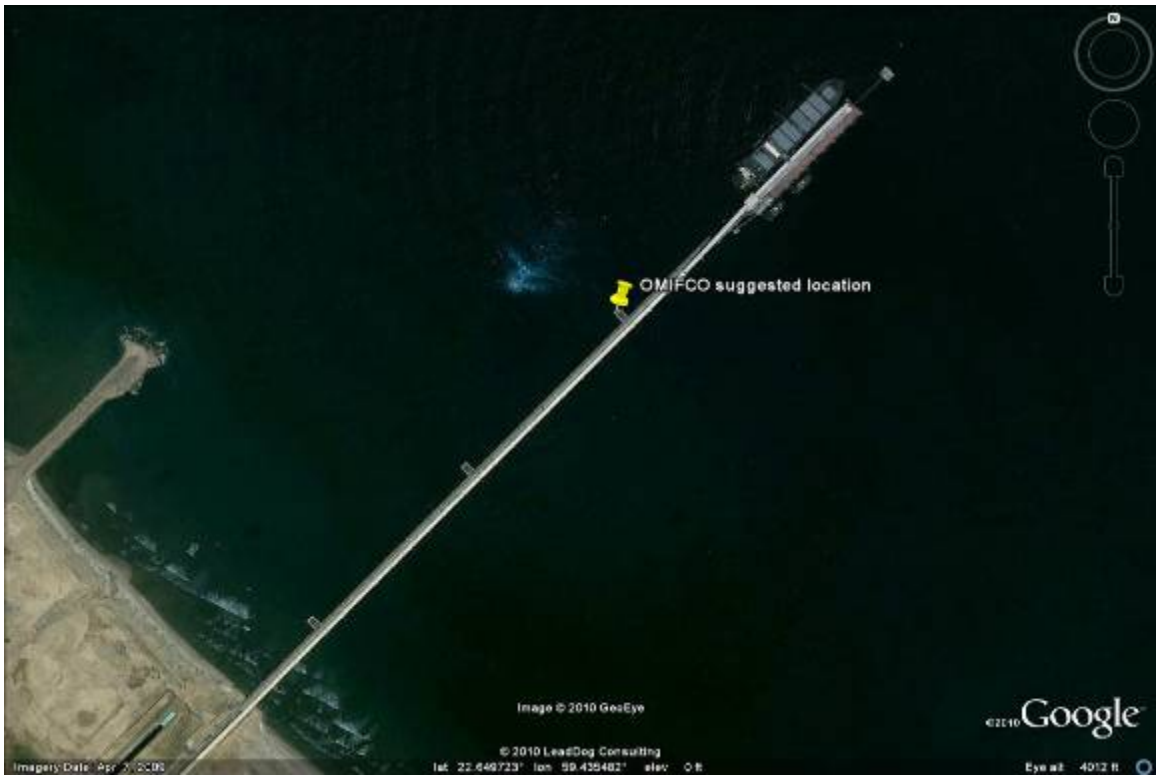


Figure 14

Security:
The port has strict security controls and is completely closed to the public due to the scale of investment in the plant and the hazardous nature of the ammonia. Manned gates control access to various parts of the port.

Solar and satellite sky view:
The sky view for all the satellites considered in this report and for solar photovoltaic panels at the proposed location was unobstructed.

Mobile phone signal:
Oman Tel: 5 bars
Nawras Tel: 5 bars

Electrical service:
Electrical service for equipment on the jetty could be arranged but would require specific engineering to be safely integrated.

Benchmark networks:
Mr. Khalfan Al saadi was not aware of specific benchmarks in the port.

Conclusion:
While it may be possible, attempting installation of a tide gauge system at this location is not recommended. The administrative and technical challenges of installing equipment here would be significant.

Qalhat Liquid Natural Gas Plant, Oman

Visited November 9, 2010. No direct inspection of the jetty was possible due to security and safety regulations. No photography was permitted.

Main point of contact interviewed at plant:
Mr. Atiq Ahmed, Marine Superintendent, Oman LNG (see business card in appendix).

General port description:
The Qalhat Liquid Natural Gas (LNG) Plant in Oman is a major industrial facility used for liquefying and loading natural gas onto cargo ships. It is located near the town of Sur about a 3-hour drive from Muscat. According to Mr. Ahmed, the construction of the facility required over 400 million man-hours and the company now contributes about 10% of Oman's gross national product. See the Qalhat LNG web site for additional details: http://www.qalhatlng.com/.

Meteorological and other related sensors and systems:
The control center operates meteorological sensors, a tide sensor and a WaveRider buoy system http://www.datawell.nl/inhoud.php?id=3 (see figure 15 for a general view of the location of these sensors). The data from these sensors is collected and displayed using a software package called DockMaster 5 from the Marimatech Company. See the Marimatech company website for additional details: http://www.marimatech.com/.

Figure 15

Potential for tide gauge equipment:
The Qalhat LNG facility is not a practical place for the installation of a tide gauge system. The facility is highly engineered and any new equipment would need to pass exhaustive testing and require specific engineering for its installation, especially on the jetty itself. It is likely that many parts of a normal tide gauge system are not tested and approved so as to meet the safety regulations required due to the flammability of natural gas. Even if permission were granted to install tide gauge equipment, anyone working on the installation or maintenance of the equipment would need special training and authorization to work inside the facility. The jetty is very tall to accommodate the large ships it services and is not protected by a breakwater from open sea. Both these factors would further add to the challenge of installing a tide gauge system.

The control center at Qalhat LNG already monitors tide data along with many other marine and meteorological parameters. It is possible this data could be collected and provided to other agencies for scientific purposes. It is also possible this data could be relayed in near-real-time for tsunami or other warning purposes by contacting the Qalhat LNG administration and the Marimatech Company to request it.

Security:
The port has strict security controls and is completely closed to the public due to the scale of investment in the plant and the hazardous nature of the natural gas. Access to various parts of the port is controlled by manned gates and coded access cards.

Solar and satellite sky view:
There was no opportunity to review this for a specific site. Obstructions would come from parts of the facility only, not from mountains or other natural geography.

Mobile phone signal:
Oman Tel: 5 bars
Nawras Tel: 5 bars

Electrical service:
There was no opportunity to review this for a specific site.

Benchmark networks:
There was no opportunity to review this for a specific site.

Conclusion:
Attempting to install a tide gauge system at this location is not recommended. If data is needed from this site, investigating how to access the data already being collected by the facility’s own sensors and systems would be a better choice.

Qurayat (Qurayyat) Fisheries Port, Oman

Inspected November 9, 2010. Measurements and photos taken at 9:00 AM local time. Tidal state at time of measurements and photos according to predictions: approximately 2.4 m above chart datum. Z_0: 1.89 m above chart datum.

Main point of contact interviewed at port:
Nasser Bin Saleh Al-Gazali, Managing Department Fisheries Wealth. (See business card in appendix.)

General port description:
The port of Qurayat is a small fisheries port in the small town of Qurayat about a 1.5-hour drive from Muscat. There is a port office and a police office inside the port. During this inspection, there was very little activity at the port. Mr. Al-Gazali was not aware of any previous tide gauge equipment. Mr. Al-Gazali said the port was constructed in about 1996.

Meteorological and other related sensors and systems:
No meteorological or other sensors were observed.

Potential for tide gauge equipment:
There is one good location for a tide gauge at this port along the south wall of the main concrete jetty, landward of the port petrol station. The best spot on this wall is approximately 1.3 m seaward of the landward-most rubber boat bumper in between the 7^{th} and 8^{th} (from shore) concrete yellow-and-black painted concrete blocks (see figures 16 and 17). See the appendix for additional photos. This spot was chosen to be as far from the petrol station and the actively-used east face of the jetty as possible, while still having sufficient water depth. This area has a concrete deck, which is sloped 1 or 2 degrees seaward. There is a vertical concrete wall extending about 2.7 m down from the deck. The distance between the deck and the water at the time of the photo was approximately 150 cm and the depth of the water at the time of measurement was about 3.5 m. Siltation could become an issue at this dock and at all the fisheries ports examined, but it appears that dredging of these ports is done as needed. The recommended area appears to be out of the way of ship operations. All standard components of a tide gauge could be easily installed here. Two vertical steel posts should be installed as guards against vehicles bumping the equipment after its installation.

Figure 16

Figure 17

Security:
The port is open to the public 24 hours a day. It is monitored by police and port officials. Despite the lack of controlled access, it appears the threat to tide gauge equipment from theft or vandalism here and in most of Oman is small.

Solar and satellite sky view:
The sky view for all the satellites considered in this report and for solar photovoltaic panels at the proposed location was unobstructed.

Mobile phone signal:
Oman Tel: 5 bars
Nawras Tel: 5 bars

Electrical service:
There is a utilities trench covered by a series of flush-fitting concrete blocks running parallel to the suggested jetty wall about 1 m from the edge of the jetty. Electrical service should be possible with minor concrete trenching to this trench.

Benchmark networks:
No benchmark networks were found and Mr. Al-Gazali was not aware of specific benchmarks in the port.

Conclusion:
The location at Qurayat is a good place for a modern satellite transmitting tide gauge. The water depth at the proposed location is a little shallower then ideal but meets the minimum requirements generally used.

Sohar (Majis) Port, Oman

Inspected November 7, 2010. Measurements and photos taken between 11:00 AM and 12:00 PM local time. Tidal state at time of measurements according to predictions: approximately 2.25 m above chart datum. Z_0: 1.97 m above chart datum.

Main point of contact interviewed at port:
Hashim Al Bloushi, Marine Safety Officer, Port of Sohar. (See business card in appendix.) For future contacts, Mr. Bloushi suggests Mr. Batti Al Shibli, Assistant Harbor Master (see business card in appendix).

General port description:
The port of Sohar, previously known as Majis, is a major shipping port. It is about a 2.5-hour drive from Muscat. Traditionally a fishing town, it is more recently known as Oman's industrial hub due to the massive developments in the Sohar Industrial Port. Sohar Port is considered a world-class port. With current investments exceeding US$ 12 billion, it is one of the world's largest port development projects (Wikipedia). See the port's web site for additional details: http://www.portofsohar.com/.

Meteorological and other related sensors and systems:
The Meteorological Department of Oman operates a manned meteorological station adjacent to the port, though it was reported it would be moved to make room for new construction. At this office there was a display and radio receiver of a submerged wave-, tide-, and current-sensor array relaying data to the Meteorological office by radio, however it is currently not functioning. The port control center operates an offshore buoy, which sends meteorological, wave, tide, and current information to the port control office.

Potential for tide gauge equipment:
Two potential sites for installing tide gauge equipment were examined: The southeast end of Berth # 3, also known as Urea Berth, and the northwest corner of the main basin, known as Service Berth.

1 – Urea Berth (option A)
As part of the security measures in this section of the port, photographs were prohibited, so it is not possible to include any in this report. This site has a concrete deck and vertical concrete wall. The vertical concrete wall extends at least 3 m down from the deck. At the time of the visit, the water level was about 2 m below the deck. The site has deep water. The recommended area for the tide gauge appears to be out of the way of ship docking and loading operations (see figure 18). This area is landward of the first bollard on this face of the dock and seaward of a security fence. This area of the port is leased by and under the control of C. Steinweg Oman Corporation: http://www.steinwegoman.com. Arrangements for placing equipment here would have to be through them and the Port of Sohar. This part of the dock is used for loading Urea into ships via an overhead conveyor belt system. Dust from the conveyor belt system could potentially interfere with solar panels or antennas. Significant amounts were observed during the visit. Mr. Al Bloushi reported that the Royal Navy of Oman previously installed a temporary tide gauge in this same location. All standard components of a tide gauge could be easily installed here. Two vertical steel posts should be installed as guards against vehicles bumping the equipment after its installation.

Figure 18

2- Service Berth

This location is in a corner of the port with the Service Berth dock on the northwest side and a future container terminal on the southwest side (see figures 19 and 20). See the appendix for additional photos. This area has a concrete deck. There is a vertical concrete wall on the southwest side and a vertical corrugated steel-sheeted wall on the northwest side. The Service Berth dock is used for port service boats such as tugboats and is under control and ownership of the Port of Sohar. The equipment should be placed on the northwest side to remain within the area controlled by the Port of Sohar. The recommend area is between the corner and the first landward bollard on this dock face (bollard labeled: QSR-B01). The distance between the deck and the water at the time of the photo was approximately 245 cm. The small building immediately behind the area is the tug pilot's office. The recommended area appears to be out of the way of ship operations. All standard components of a tide gauge could be easily installed here. Two vertical steel posts should be installed as guards against vehicles bumping the equipment after its installation.

Figure 19

Figure 20

Security:
The port has strict security controls and is completely closed to the public. Access to various parts of the port is controlled by manned gates.

Solar and satellite sky view:
Sky view at the Urea Berth location appears obstructed towards METEOSAT 9 due to the overhead conveyor system used to load urea onto the ships. It also appears obstructed towards INMARSAT BGAN I-4 EMEA due to storage tanks. The view towards METEOSAT 6 & 7 appears clear.

Sky view at the Service Berth location is currently unobstructed. However, future expansion plans call for a new container loading dock directly southwest of this area and depending on the design of the dock and placement of containers, any of the reviewed satellites could be obstructed. According to Mr. Al Bloushi, plans for this expansion have not been finalized.

Mobile phone signal:
Oman Tel: 5 bars
Nawras Tel: 5 bars

Electrical service:
Possible with minor concrete trenching at both locations.

Benchmark networks:
No benchmark networks were found and Mr. Al Bloushi was not aware of specific benchmarks in the port; however due to the nature of the port it is likely that a network of benchmarks exists to monitor subsidence.

Conclusion:
All standard components of a tide gauge could be easily installed at both locations. Two vertical steel posts should be installed as guards against vehicles bumping the equipment after its installation. The Urea Berth location has limited sky view and would be slightly more complex to arrange permission for, since the area is owned by the Port of Sohar but leased by the C. Steinweg Oman Corporation; however there are no plans for expansion in this area. The Service Berth location seems the better choice since it has an open sky view and is directly under control of the Port of Sohar; however, future construction in this area could potentially obstruct the satellite sky view.

Sur Fisheries Port, Oman

Inspected November 10, 2010. Measurements and photos taken at 8:30 AM local time. Tidal state at time of measurements and photos according to predictions: approximately 1.9 m above chart datum. Z_0: 1.77 m above chart datum.

Main point of contact interviewed at port:
Abdullah Al-Hadabbi, Sur Port Director, frqasm@hotmail.com, mobile +968 995 85 858

General port description:
The port of Sur is a small fisheries port in the small town of Sur about a 3-hour drive from Muscat. There is a port office and a police office inside the port. There were several police boats there during this visit. A new concrete-walled dock was just being completed during this visit. Mr. Al-Hadabbi was not aware of any previous tide gauge equipment. The Oman Ministry of Fisheries Wealth has a web site describing the Sur port here: http://www.mofw.gov.om/english/tabid/419/Default.aspx.

Meteorological and other related sensors and systems:
No meteorological or other sensors were observed.

Potential for tide gauge equipment:
There is a potentially good location for a tide gauge at this port along the southwest wall of the new concrete jetty. This is the only section of concrete walled jetty that appears to be out of the way of most boat operations. The best spot on this wall is just landward of the landward-most rubber boat bumper (see figures 21 and 22). See the appendix for additional photos. This spot was chosen to be as far from the main operational face of this new jetty as possible while still having sufficient water depth. The area has a concrete deck and a vertical concrete wall reported to extend to the seabed. The top edge of the concrete deck is rounded. About 50 cm down from the deck is a small undercut lip after which the wall continues down about 5 cm in from the upper face. The distance between the deck and the water at the time of the photo was approximately 198 cm and the depth of the water at the time of measurement was about 5.5 m. The suggested location is landward of the first large bollard, but seaward of a small bollard. The location of this small bollard indicates the area may be used for small boat operations. If an open-air radar-based sensor were installed here, arrangements would need to be made to prohibit boats from parking near it. The area encompassed by the new jetty walls and immediately behind the suggested site is still under construction and it was not possible to find out what will be built there. Siltation could become an issue at this dock and at all the fisheries ports examined, but dredging of these ports appears to be done as needed. It was reported that dredging was recently done at this port. All standard components of a tide gauge could be easily installed here. Two vertical steel posts should be installed as guards against vehicles bumping the equipment after its installation.

Figure 21

Figure 22

Security:
The port is open to the public from 6 AM to 10 PM daily. It is monitored by police and port officials. There was a lot of police activity and police boats docked in the immediate area of the suggested tide gauge site during this visit. It appears the threat to tide gauge equipment from theft or vandalism here and in most of Oman is small.

Solar and satellite sky view:
The sky view for all the satellites considered in this report and for solar photovoltaic panels at the proposed location was unobstructed.

Mobile phone signal:
Oman Tel: 5 bars
Nawras Tel: 5 bars

Electrical service:
Electrical service should be possible with minor concrete trenching.

Benchmark networks:
No benchmark networks were found and Mr. Al-Hadabbi was not aware of specific benchmarks in the port.

Conclusion:
The location at Sur is a good place for a modern satellite-transmitting tide gauge; however it is important to determine first what construction is planned for the area immediately behind the proposed tide gauge site, in case it conflicts with using the area for a tide gauge.

Wudam Port, Oman

Inspected November 8, 2010. Measurements and photos taken at 10:45 AM local time. Tidal state at time of measurements and photos according to predictions: approximately 2.7 m above chart datum. Z_0: 1.87 m above chart datum.

Main point of contact interviewed at port:
Nasser Al Harthi of the Royal Navy of Oman Hydrographic Survey Unit. Email: alkhtab01@hotmail.com. Mobile +968 960 99 069 Office +968 263 45 611

General port description:
The port of Wudam is the main naval base for the Royal Navy of Oman. See the Royal Navy of Oman web site for additional details: http://rno.gov.om/English/index.php.

Existing tide gauge equipment:
The Royal Navy of Oman has operated a tide gauge at Wudam port for more than 20 years. Originally the tide gauge was an OTT mechanical chart-based recorder using a float in a stilling well. In approximately 2007 this gauge was replaced with a digital OTT pressure sensor/data logger also in a stilling well (see figures 23 and 24). There is also a wooden painted tide staff. See the appendix for additional photos.

Figure 23

Figure 24

Potential for new tide gauge equipment:
On the dock in between the old and new tide gauges there is ample room for an additional satellite-transmitting tide gauge. This area is out of the way of ship operations and has an unobstructed sky view. This section of the dock is used only for the tide gauge. It is shoreward of the first bollard so there is no risk of damage from ship operations. There is a concrete deck and vertical concrete wall. The wall extends down from the deck about 140 cm. The water at the time of inspection was more than 4 m deep. The stilling well previously used for the OTT float-based chart recorder appears to be in good condition and could potentially be reused for modern sensors. The OTT recorder would need to be removed for a complete inspection of the well. The stilling well pipe is approximately 30 cm in internal diameter. The distance between the deck and the water at the time of the photo was approximately 210 cm, which corresponds to a reading on the tide staff of 3.21 m.

Permission would need to be obtained from the Royal Navy of Oman. It appears they would welcome an additional tide gauge on this site. The Navy has a hydrographic office located at Wudam and could easily provide support and maintenance to new equipment located there. All standard components of a tide gauge could be easily installed here.

Security:
Since this port is a naval base, it has strict security controls and is closed to the public. Access to various parts of the port is controlled by manned gates.

Solar and satellite sky view:
The sky view for all the satellites considered in this report and for solar photovoltaic panels at the proposed location was unobstructed.

Mobile phone signal:
Oman Tel: 5 bars
Nawras Tel: 5 bars

Electrical service:
Possible with minor concrete trenching.

Benchmark networks:
The navy maintains a network of benchmarks in support of their tide gauge, which they survey regularly. The nearest benchmark to the tide gauge is about 15 m northwest of the gauge in the corner of the jetty and is labeled RNO BM621.

Conclusion:
The location at Wudam is a fine place for a modern satellite-transmitting tide gauge.

Tide Gauges Operated by the University of Hawaii Sea Level Center:

The University of Hawaii has been operating tide gauges in Oman since 1987 and began transmitting data via satellite in 1991. Currently they operate three tide gauge stations: One at Mina Qaboos Port in Muscat, one at Port Raysut in Salalah and one on the island of Masirah

All three sites transmit water level data on a 15 minute cycle to the Eumetsat METEOSAT satellites. They are battery powered and solar charged. In addition to the transmitted data, data is backed up locally on site with a capacity for more then 10 years of data storage. System clocks are GPS controlled.

All three sites use all of the following water level sensors types:

- Submerged balanced pressure transducers
- Open air radar sensors
- Float based shaft encoder sensors
- Reference level float switches

All three sites have in addition to the main data logger/satellite transmitter, an additional back up data logger recording a single water level sensor with an independent solar charged battery power system and independent GPS clock correction.

All three sites have a network of bench marks established in the vicinity of the tide gauge used to regularly monitor the vertical stability of the equipment.

The site at Mina Qaboos, Muscat has an additional independent system transmitting water level data every 5 minutes via the INMARSAT BGAN satellite internet system. This system operates a single submerged balanced pressure transducer and has its own solar charged battery power system.

Masirah tide gauge

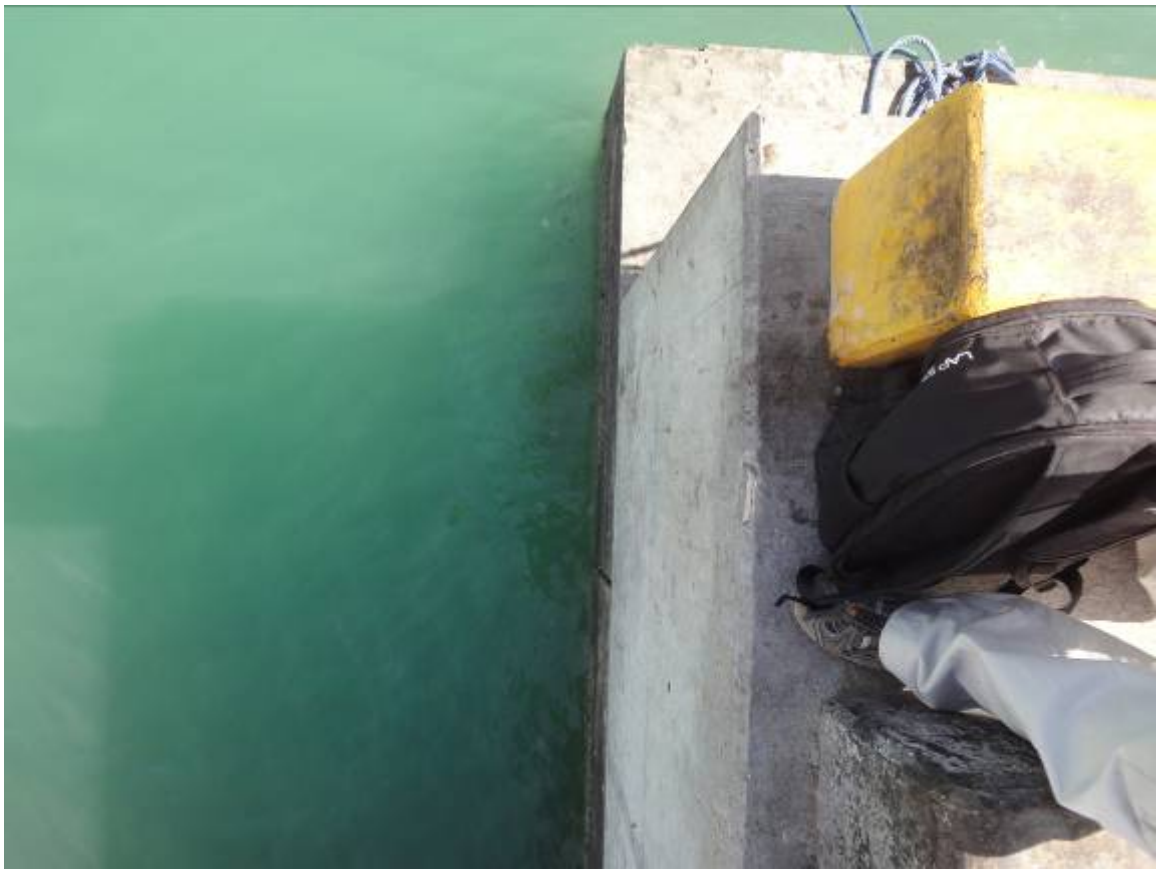
Salalah tide gauge

Muscat tide gauge

Al Ashkhara Fisheries Port, Oman, Additional Photos

Panorama view of port area from boat ramp at southeast corner of improved section of port

View of suggested tide gauge location from the west



View of suggested tide gauge location from above

Long view of suggested tide gauge location from the south

Daba (Dibba) Al Baya Fisheries Port, Oman Additional photos

Panorama view from floating dock at the south end of the port

Long view of suggested tide gauge sites from the east

Suggested sensor location in vertical notch in concrete pier face

Meteorological sensors observed inside port area

Mr. Bin Ali Shihi and Mr. Turetsky

Duqm Port, Oman Additional photos

Panorama view of site B from the east

Artist’s rendering of completed port

View of site B from the northwest

Qurayat (Qurayyat) Fisheries Port, Oman, Additional Photos

Utility trench adjacent to suggested tide gauge site

Panoramic view of port area

Long view of suggested tide gauge site from south

Floating docks at south end of port

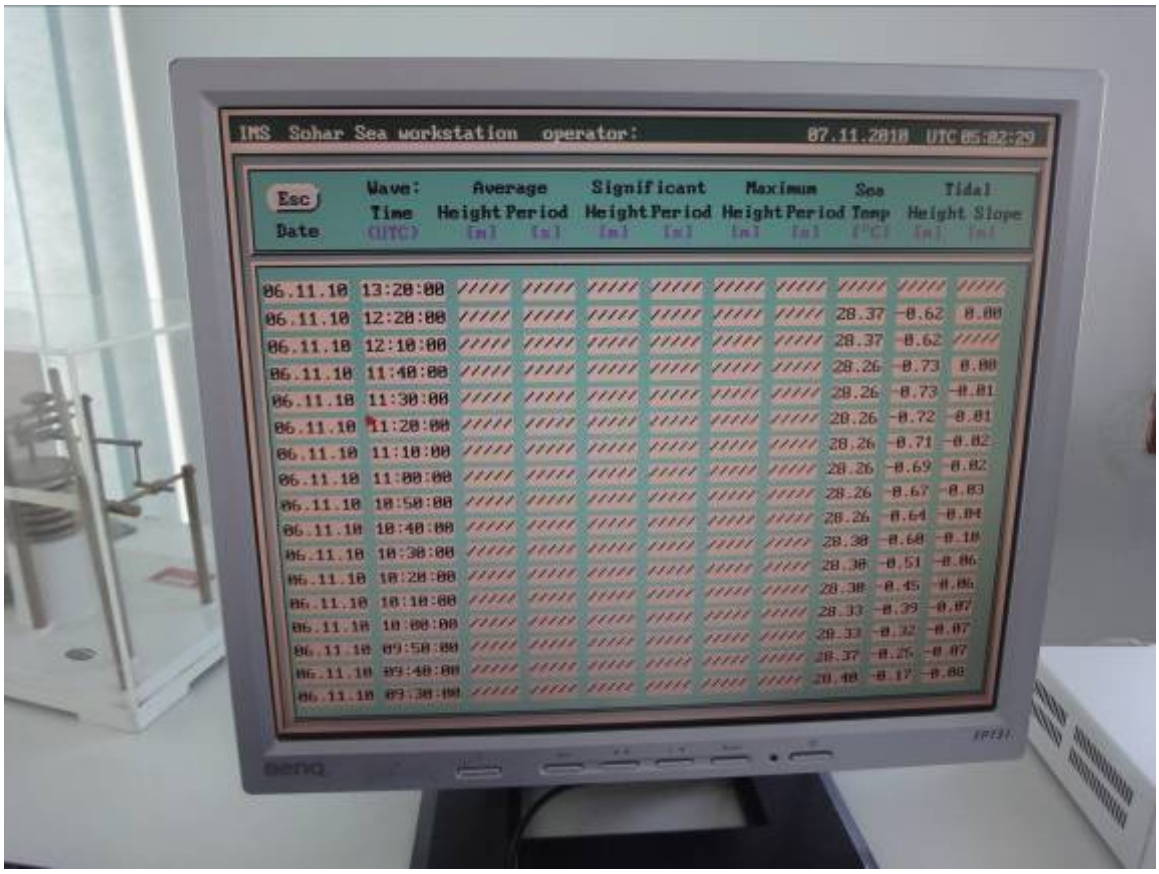
View of north end of main jetty

View from north end of main jetty

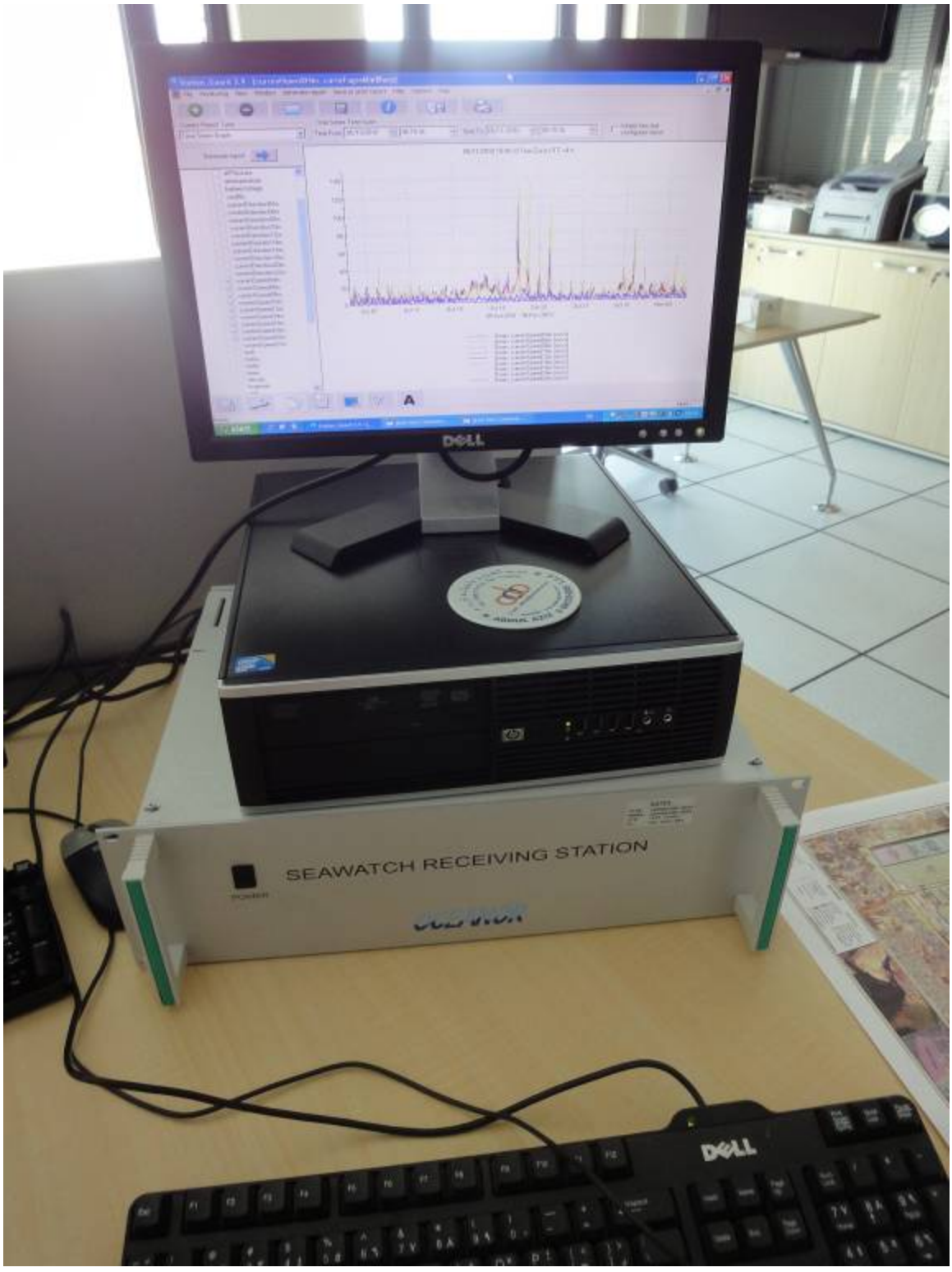
View of suggested tide gauge site from north

View of suggested tide gauge site from west

Sohar (Majis) Port, Oman, Additional Photos



Wave-, current-, and tide-sensor display at MET office



Buoy data received at port control center

Meteorological sensors at meteorological office

Mr. Al Bloushi and Mr. Turetsky

View of Service Berth tide gauge site from northeast

View of Service Berth tide gauge site from above

Panorama view of suggested tide gauge site

Diagram of Port of Sohar

Sur Fisheries Port, Oman, Additional Photos

Panorama view of port from boat ramp on southwest shore of port

View of suggested tide gauge site from southeast

View of suggested tide gauge site from above

View of signs describing construction adjacent to suggested tide gauge site

Photo of Mr. Al-Hadabbi and Mr. Turetsky

Wudam Port,Oman Additional Photos

OTT sensor control and data download device

Control port on top of OTT pressure sensor assembly

OTT float-based mechanical chart recorder

Benchmark adjacent to tide gauge

Close view of bottom of OTT chart recorder above stilling well