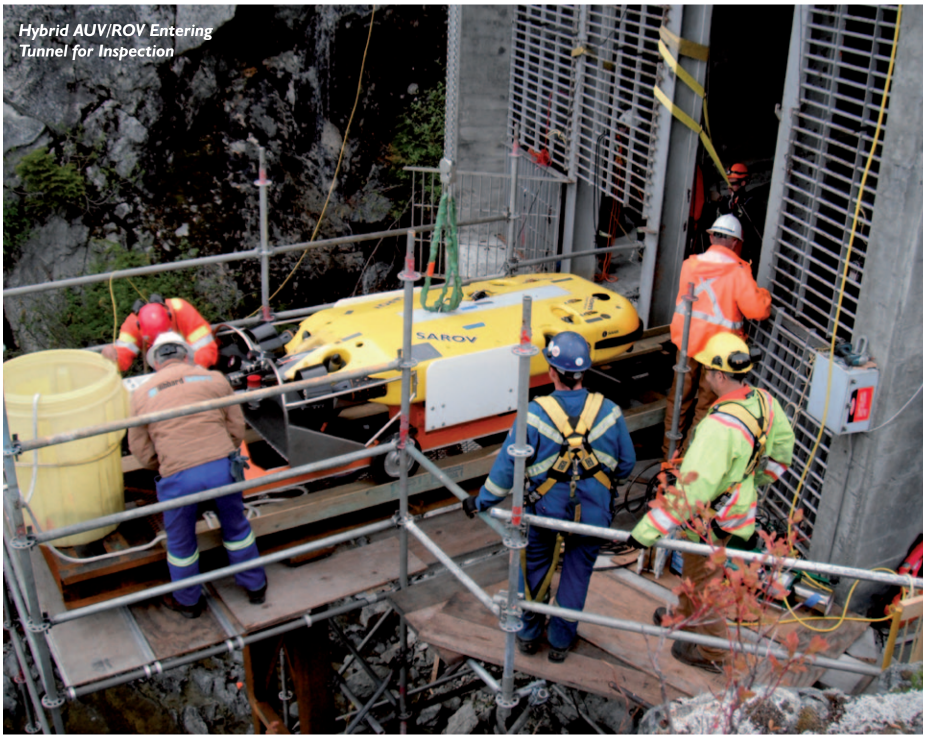
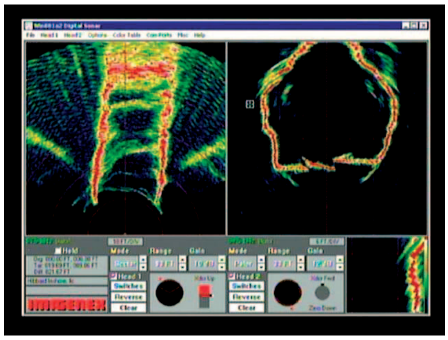
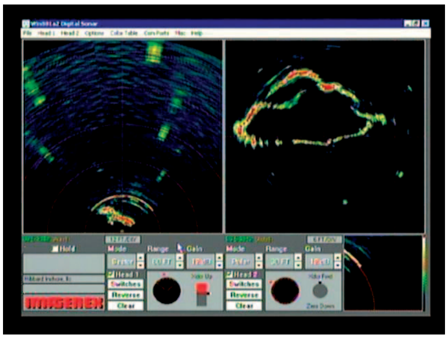
CASE STUDY: INSHORE ROV

HIBBARD INSHORE



Hybrid AUV/ROV Entering Tunnel for Inspection


Profiling Sonar showing crown failure in tunnel


Profiling Sonar showing loss of material at crown and heavy sediment in bottom of tunnel

The act of inspecting and maintaining the underwater portions of hydroelectric dams has presented unique challenges since the first facilities came on line in the late 1800s. Until the mid-1980s, the options for inspection were to either dewater the portion of the dam to be inspected or to use commercial divers to perform the inspections where safe and possible. Dewatering of long tunnels and high head dams in particular, presents a number of large challenges. Plant downtimes are typically long, fisheries are impacted, and the structure can be stressed. The draining of water removes the added structural support normally provided by the water pressure and allows materials to dry and contract potentially expediting cracking and degradation. Since the mid-1980's, however, fewer inspections involving dewatering have had to be undertaken as technological advances have continued to occur in the underwater robotics systems known in the industry as remotely operated vehicles (ROVs).

These advances in ROV technology have allowed inspection and maintenance work that was previously very difficult or impossible to perform due to low visibility, deep water, long distance confined entry, or potential underwater hazards now to be completed in a fully-flooded state with little risk to human life and minimal generating outage times. Performing inspections in this manner provide additional benefits as well. The shortened, reduced-flow time periods or outages required due to today's technology minimize environmental impact to valuable fisheries, and undue stress is not placed on the structure by removing the water.

Today, it is widely accepted that underwater inspection of critical assets should be a major component of the preventative maintenance plan of any hydroelectric facility. There are three recent jobs completed by Hibbard Inshore that illustrate various considerations as to why it is a major advantage for power generating companies and their insurance providers to perform regular inspection of the underwater assets at their facilities. Rather than dewatering, all three of the inspections in this study were performed with ROVs. These vehicles were fitted with color and low-light monochrome video along with multiple forms of sonar to allow potential flaws to be identified in the structures. The vehicles were each specified to the particular project based upon access considerations, depth of the structures, allowable outage/reduced flow time period, distance the vehicle would have to swim during the inspection, and data the customer wished to obtain during the inspection.

In this paper we will explore these three cases:

- **A relatively new hydroelectric facility with long range tunnels and deep shafts in Asia**
- **A hydroelectric facility with a large tunnel collapse in the Americas**
- **A hydroelectric facility feeding critical manufacturing that could not be shut down for inspection**

The first case discussed here involves a facility with a tunnel of over 5 km and depths in excess of 300 meters. Due to the long distance of the tunnel and the deep water at the facility, this inspection was carefully planned to utilize the latest ROV capabilities because it would have been a major setback in the region to have to take the facility offline for dewatering. The facility provides not only the power for the local cities and towns but also is a source of revenue for the region. Because of the length of the tunnel and access constraints, previously available technology would only allow for a portion of the tunnel to be inspected effectively. This facility required inspection because its warranty period with the construction company for the facility would expire shortly, and the owner wanted to be sure the facility was both built properly as indicated in the as-built drawings and was standing up to the rigors of operations prior to warranty expiration.

Like with many pieces of technology, ROVs have continued to grow more capable while experiencing reductions in size and overall cost. The reduction in size has increased the number of areas they can access as well as the cost of shipping and operations. These advances allowed for the inspection to be completed in early 2011.

The ROVs used were a Hibbard Inshore modified Sub-Atlantic Navajo with a 5km tether and a deep rated Seabotix LBV which were able to complete the long tunnel inspection along with inspections of several other structures while minimizing facility outage time. These systems were shipped via air

20+ km Hibbard Inshore Saab Hybrid AUV/ROV

freight to meet the project timeline during the region's dry season, and the smaller size of the vehicle systems allowed them to be easily trucked from the airport into the mountainous region of the facility.

The inspection was completed during several scheduled outages to inspect portions of the structure in a scheme designed to reduce the total outage of the plant and to fit within the daily outage limits. The inspection was accomplished through not only using video cameras and appropriate lighting but also using multiple sonar units and data acquisition software to increase the speed of inspection while still accurately identifying significant flaws and features. Since sonar uses sound waves to detect reflective surfaces, it can be used to identify features such as open cracks, joints, concrete spalling, sediment buildup, rock or concrete loss, out of round conditions (in the case of pipe), and general shape anomalies that differ when compared to as-built drawings. These features can often be seen on sonar from longer distances than a video camera can see allowing the vehicle to quickly assess the structure. The vehicle was driven through the tunnel utilizing its sonar to detect the presence of these types of features, and upon finding one on the sonar, visual confirmation was completed by flying the vehicle directly to the area of interest for a close look with its cameras. Cross-sections were taken at many of these points for dimensional measurement purposes. During the inspection, the ROV was able to locate a number of features that would potentially jeopardize the operation of the facility in the future were they not rehabilitated. From the inspection, sizes and locations of these features were determined, and the owners were able to put a repair plan in place to be financed under their warranty claim saving them a potentially difficult situation down the road.

The second case involves a facility where the construction warranty had recently expired. This facility contacted Hibbard Inshore after a loss of generating capacity was experienced shortly after seismic activity in the region. Due to the loss of generating capacity, it was thought that the intake tunnel may have experienced a small blockage due to material shaking loose during the seismic event. At this facility, the intake tunnel was approximately 10 meters in diameter and close to 5 kilometers in length. The entire tunnel needed to be inspected in a very short outage period to allow generation to continue while quantifying the amount of damage, if any, to the tunnel.

Hibbard Inshore utilized a Sub-Atlantic ROV with 2.2 km tether to undertake this inspection. The ROV was inserted into the tunnel from two access points, at the Surge Shaft and at the Intake. This allowed the use of the shorter range tether and the smaller shipment size allowed for expedited shipping at a lower cost to the customer. Upon entry into the tunnel, the ROV inspected in both upstream and downstream directions from the Surge Shaft on consecutive days and then was picked up and moved to the Intake in order to access the tunnel at that point. During the inspection, it was found that the damage to the tunnel was more extensive than expected. Due to the extent of this finding, it was determined that the tunnel would need major repair in order to continue to function. The Hibbard Inshore findings were able to tell the owner the extent of the damage so that estimates could be done for the cost of repair and submitted to the insurance company. The inspection allowed the engineers to evaluate the situation to determine as to whether the conditions were pre-existing and exacerbated by the seismic activity or solely due to that particular event. In events such as with this inspection, ➤

'TODAY, IT IS WIDELY ACCEPTED THAT UNDERWATER INSPECTION OF CRITICAL ASSETS SHOULD BE A MAJOR COMPONENT OF THE PREVENTATIVE MAINTENANCE PLAN OF ANY HYDROELECTRIC FACILITY.'

5 km Long Range Navajo and 600 Meter Rated LBV ROVs with Hibbard Crew

the technology is available to make determinations about the condition of the tunnel in a quick manner with minimum effect to production prior to warranty expiration allowing owners to have confidence in the lifespan of the asset and the insurer to minimize risks.

The final case where the technological advances of ROVs have been able to make a major difference in tunnel inspection is a case where a major manufacturer had a hydroelectric facility that generates 24 hours per day, 7 days per week in order to meet the high energy needs of the metals facility. Because of this generating schedule and the fact that 100% of the plant's power output is always used, the plant had little opportunity to slow the flow of water through their intake tunnel which was over 15 km in length. They required their inspection to be done while maintaining a minimum flow to continue to provide power to critical assets during the inspection.

In order to complete this inspection, a very powerful Saab Hybrid AUV/ROV was utilized. This vehicle is designed to run in either autonomous underwater vehicle (AUV) configuration or in a standard, tethered ROV configuration. As opposed to typical ROVs which are powered through their tethers, this vehicle has an onboard battery system allowing its tether to be used only for control and data transmission. Not having to run power to the vehicle allows the tether to be much smaller, weigh much less, and create less friction. The tether was only 3.6 mm in diameter keeping the tether weight quite small. These are all important considerations when inspecting long tunnels in flow, and the reduced weights also were helpful for onsite logistics because the facility was in a remote region requiring much of the equipment to transport via helicopter.

Because of this design and the high power of the vehicle, a flow of 0.8 m/s was able to be maintained while the vehicle completed the inspection within two separate eight hour periods. The vehicle was outfitted with stability and tracking programs to allow it to stay level in the flow as well as to know exact distance from known stationing at any given time. It also has a true 6 degrees of freedom allowing it to stand on end to maneuver through vertical sections as sometimes found near powerhouses or rock traps. The Hibbard Inshore Saab vehicle additionally carried imaging and dimensioning sonar units along with video cameras. The combination of sensors along with the high thrust, real-time control, and stability of the vehicle allowed the tunnel to be truly inspected for the first time since its commissioning. Because of this technology, the plant was able to continue production with only a very minimal slowdown preserving the revenues of the manufacturing facility.

These three jobs highlight just a few of the types of vehicles available to aid power generation facilities in lifespan assessment of their underwater and hard to reach assets. In addition to the long tunnel vehicles, vehicles exist for more standard inspections such as for the face of dam, head gates and seals, intake structures, steam and nuclear plant intakes and discharges, lower outlets, and downstream aprons. Vehicles also exist that can aid in deep water dredging in front of units, deep water temporary bulkhead placement to allow work on valves or turbines, and inspection of dry tunnels where walkthrough has been deemed to potentially be unsafe. The common thread is that the improvement of technology has opened up a whole new realm of possibilities for companies to gather information about their generating assets and to implement important maintenance solutions at key times so that the facilities are able to maintain production for longer durations than ever before.