Erin Camp
Geography-333
18 June 2010

Documenting the Natural and Anthropogenic Changes to Te Awa o Te Atua During the Past 100 Years

---

ABSTRACT: Te Awa o Te Atua is an infilled lagoon that is situated on the western edge of the Rangitaiki Plains, Matata, Eastern Bay of Plenty, North Island, New Zealand. This research project quantifies the physical changes and associated effects that have occurred at the Te Awa o Te Atua lagoon in the last century. One of the primary goals of the project was to draw a contrast between the changes that have taken place naturally, such as debris flows, and those that have been created anthropogenically, such as those incurred due to the drainage scheme. Data was obtained using Ground-Penetrating Radar and hand auger logs to stratigraphically quantify the amount of debris deposited during the 2005 Matata Flow—approximately 174,000 m^3 of fine sediment. Results were integrated with indigenous knowledge of the local Maori in Matata, in order to conduct a four-pronged comparative Mauri Model assessment of Te Awa o Te Atua at various points during the lagoon's history. Results showed that both natural and anthropogenic events have lowered the lagoon's mauri over the past century, yet remediation efforts have proven successful in restoring Te Awa o Te Atua to a healthier wetland habitat.

INTRODUCTION

Cultural

The Te Awa o Te Atua lagoon, located in the Matata region of the Eastern Bay of Plenty (See Figure 1), has undergone a number of physical changes in the past century. These changes have occurred naturally and been induced artificially, ranging from local industrial pollution to landscape alterations ensuing from debris flows and floods. As a result of these modifications, the lagoon's mauri, or inherent life-quality as qualified by the Maori culture, has also been greatly affected.

Figure 1: Map of Bay of Plenty. Photo courtesy of NZ Accommodation Online.

The Maori concept of the quality and binding force of their land, or mauri, is a crucial part of their culture. If the mauri of their land is strong, the plants and animals of the Earth will flourish; on the contrary, if the mauri is weak, the wildlife will be extremely vulnerable to harmful outside forces, e.g. pollution (Morgan 2006). Therefore, mauri is often accompanied by the Maori concept of kaitiakitanga, or guardianship of the environment. It is a fundamental aspect of their relationship with the Earth and their cultural history. Maori believe that all natural resources were born from Papatuanuku (Mother Earth), including humans. Consequently, Maori uphold the belief that humans do not have possession over earthly resources; rather, the Earth has possession over men, and humans have mere 'user rights' for Earth's bounty (Marsden 1992). The indigenous Maori in New Zealand have used this principle of kaitiakitanga to protect their environment for hundreds of years, successfully protecting their resources and maintaining their relationship with the Earth. Much can be learned from the example they lead, especially in the case of sustainability legislation in New Zealand. Dr. Kepa Morgan has recently developed a multi-disciplinary sustainability assessment that incorporates the indigenous values and beliefs with scientific knowledge into a pragmatic, viable formula for sustainability decision-makers (Morgan 2006).

This report intends to qualify the historic and current mauri of the Te Awa o Te Atua lagoon using Dr. Morgan's Mauri Model Assessment. Using a balanced combination of indigenous knowledge from the model and scientific data from Ground-Penetrating Radar and hand-auger cores, the results from this report hope to create a foundation for the protection and maintenance of Te Awa o Te Atua lagoon.

Historical

The 1911 drainage scheme of the Rangitaiki Plains, the May 2005 Matata debris flow, and the Te Awa o Te Atua wetland remediation works are of great import to my research project. There has been much historical investigation relating to the drainage of the plains, especially the effects on the geology of the three major rivers and the ecology of the surrounding areas (Gibbons 1990). Extensive prior research has been conducted on the causes and mitigation strategies of the debris flow (McSaveney 2005). This project uses Ground-Penetrating Radar and hand auger cores in the field research component to quantify damages from the debris flow. Next, Dr. Kepa Morgan's Mauri Model was applied using historical research to determine the status of mauri at four different times in the lagoon's history: pre-drainage, post-drainage, post-debris flow, and post-wetland works. As two of these scenarios are the results of original/natural events (pre-drainage and post-debris flow) while the other two are the results of man-made choices and construction (post-drainage and post-wetland works), conducting a balanced comparison of the lagoon's mauri over time is achievable. The results from the four assessments will ideally provide insight into future protection of Te Awa o Te Atua from both natural disasters and anthropogenic sources.

BACKGROUND

Physical and Cultural History

What is presently the Te Awa o Te Atua lagoon is located near the coast of Matata, a small town in the Eastern Bay of Plenty. It lies on the coastal strip of the Rangitaiki Plains, which are situated at the northernmost section of the Taupo Volcanic Zone, bordered by Whakatane to the east and Matata to the west. Today there are three major rivers that flow through the Rangitaiki Plains: the easternmost Whakatane River, flowing directly to the sea; the westernmost Tarawera River, which today flows down a straight path into the sea near Matata; and the Rangitaiki River, which today meanders down to the sea at Thornton. The original courses of these three rivers, however, were much different than they are today.

About a century ago, the Rangitaiki River did not have a mouth of its own—instead, it flowed northward toward the sea, where it branched and flowed east and west parallel to the shore (Fig. 2). The westward flow joined the Tarawera River, and the combined waters traveled along the foreshore and behind the sand dunes to the sea at Matata. Te Awa o Te Atua is the formal name of what used to be this westward exit path for these two rivers—previously a rich estuarine habitat (DOC 2008).

The town of Matata is a culturally and historically significant area for the local Maori. Three Iwi express mana whenua in the sacred lands near Te Awa o Te Atua: Ngati Tuwharetoa, Ngati Awa, and Ngati Rangitihi. Matata was also a strategic battle site for Maori, notably the battle of Kaokaoroa. The remains of deceased Maori were buried in the mudflats of the lagoon, marking the land as a spiritual urupa (burial ground). Furthermore, Matata was the original landing place of the Arawa Waka, one of the first seven canoes to reach New Zealand hundreds of years ago (DOC 2008). Historically, the estuary was utilized as a safe transport alternative to canoeing through the strong shore currents, and the eastern portion of the Matata coast housed a trading port.

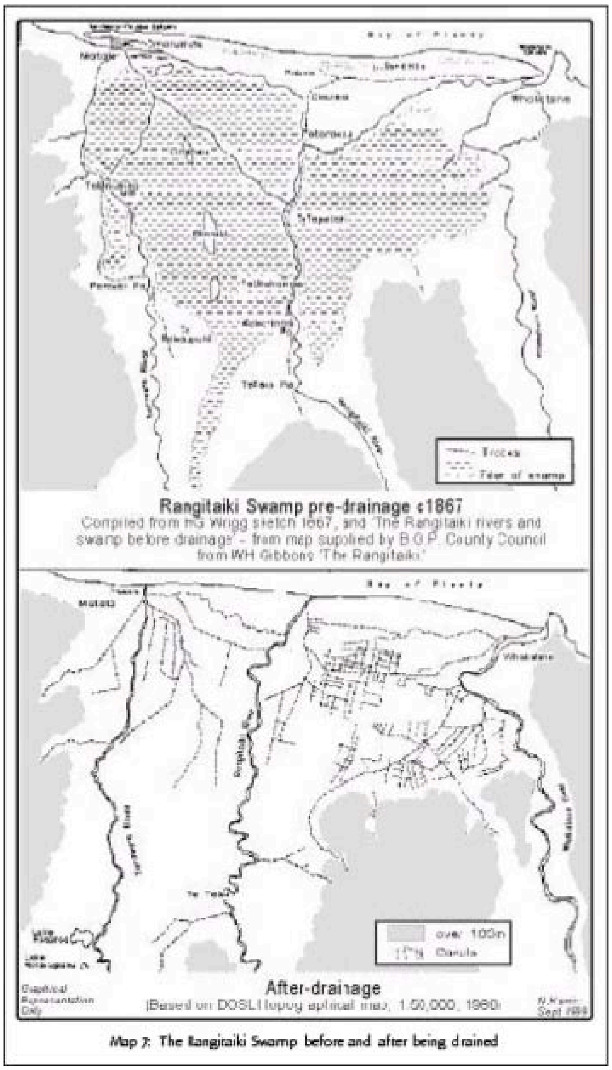

Figure 2: Rangitaiki Plains before (above) and after (below) the 1900s drainage project. Photo courtesy of Waitangi Tribunal.

Between 1911 and 1925, the Ministry of Works decided to implement a complex drainage project in the plains, in order to free up more land for agricultural purposes. As a result, the Tarawera River was diverted from its original path through Te Awa o Te Atua and forced down a new path straight into the ocean, stripping the estuary of its natural water flow source. Some of the immediate effects included rapid sedimentation, the creation of an enclosed lagoon where the estuary once thrived, the end of the port's existence, and the termination of an abundant eel food source delivered by the Tarawera and Rangitaiki Rivers (Gibbons 1990). Figure 2 demonstrates a detailed image of the Rangitaiki Plains' river paths before and after the drainage completion. Special attention should be made to the new path of the Tarawera River (left-most in the figure) flowing straight into the sea, instead of westward toward Matata. The Rangitaiki River was also punched through to the sea and nearly cut off from both the Tarawera and Whakatane Rivers.

Nearly a century later, during the 2005 debris flow, massive amounts of debris were carried down through the Awatarariki and Waitepuru Streams and into Matata, clogging up the entire western lagoon with fine sediment. This event was triggered by thunderstorm rainfall exceeding 2 millimeters per minute—twice the amount of water volume required to weaken rock and cause landslips on steep slopes. Subsequent debris flows and floods caused great damage to infrastructure and homes in the town of Matata, and massive amounts of sediment were deposited in the western portion of Te Awa o Te Atua (McSaveney 2005). Fortunately, the eastern portion of the lagoon was not nearly as severely affected (DOC 2008).

Debris floods occur at the furthest point of a debris flow, carrying the smallest particles that can be transported by the remaining water velocity. While they are less dangerous than debris flows, debris floods still have a destructive carrying capacity because they are so heavily charged with sands and silts (McSaveney 2008). Based on historical and geological evidence, it has been inferred that the deposition within Te Awa o Te Atua in March 2005 was purely debris flood material—fine sands and silts. Larger boulders and cobbles were deposited further up the Awatarariki Stream due to loss of water velocity from the decreased slope gradient.

During the debris flow, a significant amount of waste was swept into the lagoon with the sediments (Hikuroa 2010 pers. comm). However, it has been re-excavated to rehabilitate the area, alleviate the tidal fluctuations from the ocean, and to protect from future debris flows. Remediation techniques included strengthening the Awatarariki Stream's banks, digging out sediment basins, and building up excavated sediment in the form of embankments and levees (Dempsey 2005). Additionally, remediation wetlands have been established to reduce the effects of pollution from the pulp and paper mill upriver (a topic not expanded upon in this paper) and to restore the natural post-drainage habitat. Beginning in 2005, Environment Bay of Plenty, the Whakatane District Council, a Joint Advisory Committee (consisting of four members from two of Matata's Iwi and two members from the Department of Conservation), tangata whenua, and the local community combined forces to instate a Wildlife Refuge Reserve in Te Awa o Te Atua. Currently, there are two threatened plant species—*Cyclosorus interruptus* fern and the sand binding pingao—and 18 threatened species of birds. Restoration included the creation of a semi-open water habitat with indigenous plantings along the western lagoon; the eastern lagoon was left unmodified in the condition it was in post-debris flow (DOC 2008). The refuge efforts intend to protect such species, preserve the wetland habitat, and restore the mauri of the lagoon.

Present-day Lagoon and Project Preparation

The lagoon is located just north of coastal homes and properties, as well as the main highway in Matata. Due to the recent excavation of the lagoon, it has been deemed a potential danger zone. As mentioned before, the pulp and paper mill further up the Tarawera River released toxic dioxins a few decades ago, which were deposited within the lagoon. Permission from higher authorities was required before entering.

Te Awa o Te Atua has a man-made embankment on its northern shoreward boundary, created during the re-excavation process after the debris flow. The embankment is approximately a meter and a half higher than the water level of the lagoon and runs along the entire western lagoon, thus providing an excellent location to run a transect for the GPR. Because of the embankment's proximity to Te Awa o Te Atua, the GPR readings from the transect were expected to be very accurate representations of the subsurface stratigraphy. These readings were also expected to demonstrate strong reflection surfaces related to the unit of debris deposition, and perhaps even other features such as channels or faults (Wyatt 1990).

Hand auger logs are also a helpful tool when looking into the subsurface, especially when complemented with GPR data. Approximately twenty seven auger cores were taken of the area within and surrounding Te Awa o Te Atua in 2008, seventeen of which assisted in the correlation of the debris flood deposit in the GPR data (Dougherty 2009).

METHODS:

GPR

Ground-Penetrating Radar is a powerful tool used to 'survey' the shallow subsurface of the ground that is of interest to a researcher. By dragging a large box that penetrates radar waves into the ground, the researcher can receive the reflected waves in the form of stratigraphic data displayed on a computer screen. Similar units in the subsurface are denoted by similar colors; when the machine detects an unusual or unique unit, it is denoted by a distinctly different color, making it obvious to the researcher that something of note is at that location and depth. Using various wavelengths, the researcher can alter the depth at which the GPR machine sends the waves. Deeper images are of slightly lesser quality than shallower ones, but in some cases the feature of interest is quite deep, requiring a lower quality image. Collecting GPR data must also be correlated with distance to account for the uneven walking pace of the researcher; therefore, pressing a marker every so often (for example, every 50 meters) is necessary to correct the data when analyzing it on the computer software (Dougherty 2010).

Figure 3: Embankment of lagoon, which provided an ideal GPR transect.

One day was spent in the field collecting the GPR data using a SIR-2000 model, on February 18, 2010 at 10:00am. A total of two GPR transects were run, both of which were executed at wavelengths of 150 nanometers with a 200 MHz antenna. Markers were set up every 50 meters along the embankment; no markers were used on the detour routes. The main embankment was exactly 1050 meters long, so a total of 22 markers were used. The first straight GPR reading was performed to get a general image of the lagoon's subsurface (See Figure 3).

The second reading, heading the opposite direction along the same path as the previous reading, was performed in order to get readings for the water table and other interesting features that may have been near the lagoon, such as dunes. In addition to the east-west transect along the north side of the lagoon, two GPR 'detour' transects on either side of the embankment were conducted: one of which split off perpendicular to the embankment to the north and the other split off sub-parallel to the embankment to the south (See Figure 4). Both of these 'detour' transects were at lower elevations than the original embankment, nearer to the water level of the lagoon.

Figure 4: Perpendicular detour pictured left; parallel detour, right.

RTK

In order to compile the accurate elevation and spatial data for the research area, Real-Time Kinematic (RTK) satellite navigation system was utilized. This involves setting up a base station at a geologic survey mark, and recording the GPR markers using another RTK satellite rod. The base station for the research was located at a survey mark just north of the lagoon on the crevice of a water inlet flowing from the side of the embankment. RTK data was collected for each of the markers and any turnoffs associated with the detours, and names and distances of the markers were recorded. Between the two GPR readings a blank reading was saved to assure the collected data would not be overwritten by the machine.

In the lab, GPR data was analyzed using Radan software. Elevation information acquired by the RTK aided in the data normalization process – correcting the vertical ratio of the images to the accurate depth. Analysis of data from the straight transect was simple and straightforward; however, analysis of the second transect with the two detours was be a bit more difficult. It involved cropping the GPR data into three different image sheets, and normalizing each of them to the markers separately.

Hand Auger Data

Twenty-seven hang auger cores from within and around the lagoon were used to examine the subsurface stratigraphy of Te Awa o Te Atua post-flood, labeled TT1-TT27(See Borelog map, Figure 5). Each log was approximately 2 meters deep. Two main criteria were used when viewing the logs: that a debris flood deposits silty-muddy sands (McSaveney 2008), and that the debris flood was likely the last major deposition unit in this lagoon (Hikuroa 2010). In these logs there was no worry of encountering the man-made fill seen in the GPR data, since they were drilled within the lagoon as opposed to on the adjacent embankment. After consultation with other researchers of this area and local geologists, the uppermost unit in each log was deemed that of the debris flood deposit. The base of the debris flood unit was located directly above a peaty silt unit characterized by "amorphous organics," sitting above a poorly-sorted sandy gravel unit (Tonkin & Taylor, 2009). Nearly all of the borelogs showed evidence of this dual-unit sequence, except for cores TT1, TT4, TT5, and TT17. Those logs were

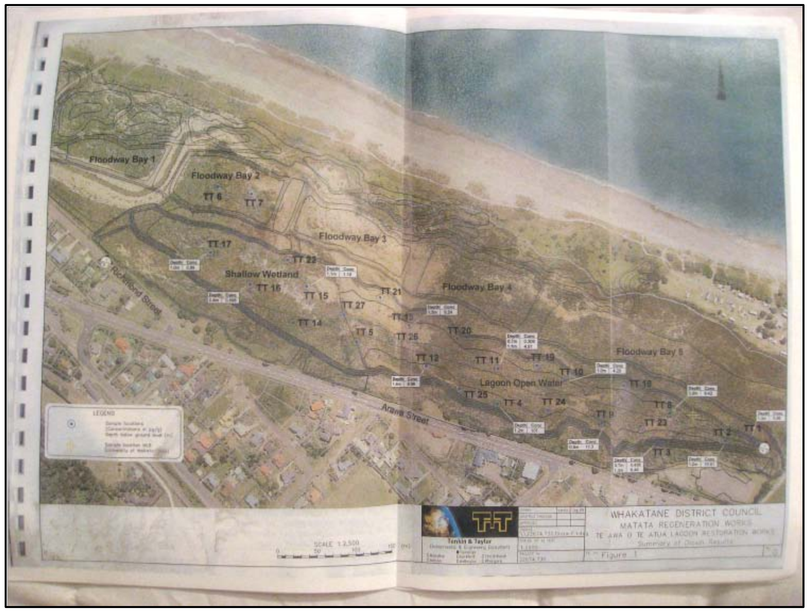

Figure 5: Borelog map of lagoon, from Tonkin & Taylor.

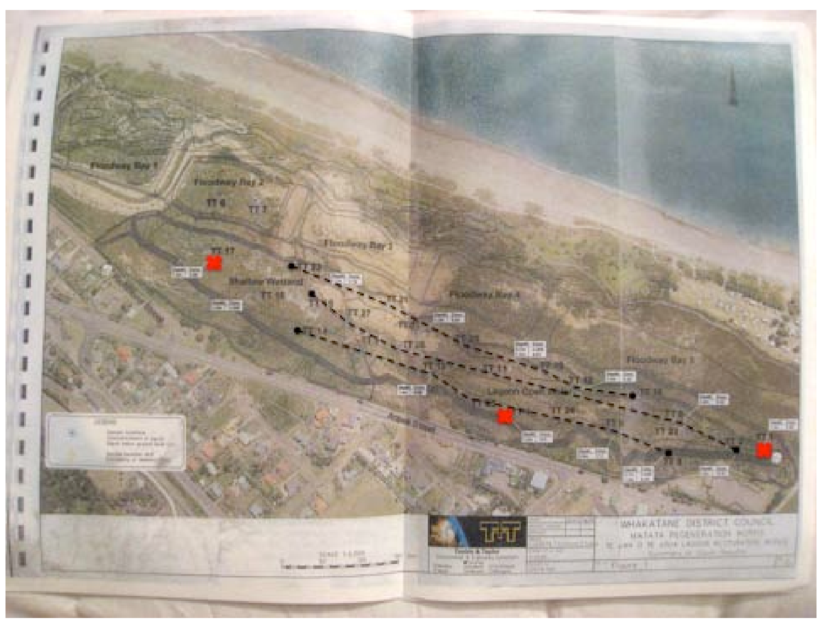

Figure 6: Modified lagoon map showing the three fence diagram transects. Original map from Tonkin and Taylor.

excluded from the fence diagrams and all further data interpretation, and were marked with a red 'X' on the transect map (See Figure 6).

Figure 7: Aerial Photo of Te Awa o Te Atua, 1987. Photo courtesy of NZ Aerial Mapping Ltd.

Using the Tonkin & Taylor borelog map, three transects were laid out across the lagoon in the west-east direction: one of the northern bank, one through the center, and the last of the lagoon's southern bank (Refer to Figure 6). Each transect was then utilized for the creation of three fence diagrams to approximate average thicknesses of the debris flood layer. The northern bank transect included six borelogs: TT15, TT27, TT26, TT11, TT8, and TT2. The central transect included six borelogs: TT22, TT21, TT20, TT19, TT10, and TT18. Lastly, the southern transect included five borelog: TT14, TT12, TT25, TT9, and TT3. Although the borelogs did not all lay perfectly on the transects, it was assumed that the margin of error was negligible for the purpose of the fence diagrams. Thus, the transects can be thought of as 'best-fit- lines. The expected result of the averaged thicknesses for the three fence diagrams was as follows: the northern and southern banks should have a slightly less thick horizon of debris flood material, due to the gradient of the lagoon. The debris flood material should have flowed and deposited more sediment in the direction of least resistance, which was via the deepest part of the lagoon rather than the edges.

Background research included a variety of articles and texts, most notably Gibbons (1990) and Brown (2006), to supplement existing knowledge of the area and the newly collected data. Additionally, aerial photos of the lagoon from March 17, 1987 were obtained during the background research process. Using two photos bearing a common location point, a stereograph constructed a 3-dimensional image of Te Awa o Te Atua (See Figure 7). This image provided a realistic visualization of the depth and location of the lagoon prior to 2005, which would have affected the deposition localities and thicknesses from the debris flow event.

Prior to conducting the Mauri Model Assessments, it was predicted that Te Awa o Te Atua's mauri would have been strongest before the drainage scheme, significantly depleted after the drainage, worst after the 2005 Matata flood, but improving slightly in the present day in response to remediation efforts.

Mauri Analysis

The Mauri Model Assessment contained four categories of sustainability analysis: environmental, cultural, social, and economic (Morgan 2006). For the purpose of this project, three indicators were chosen for each of the four categories (Hikuroa 2010). The environmental indicators of the lagoon included the estuary ecosystem health, influence of anthropogenic wastes from the mill and the dumped refuse, and sedimentation inputs (primarily as a result of the drainage scheme and the debris flow). Oversedimentation can be detrimental to both an estuary and a lagoon, and as such would detract from the mauri of either natural habitat. Wastes from the mill, deposited in the early 1900s, are still currently buried deep within the lagoon sediment. Although they have not had any negative impacts on the lagoon recently, the original waste deposition in the 1900s had toxic effects on the flora and fauna of Te Awa o Te Atua. Finally, Special attention was made to evaluate the condition of what *used to be* an estuary, rather than the condition of what *is now* a lagoon. Hence, while the lagoon may now be thriving ecologically, it still receives a low value because the evaluation is for the health of an estuary.

The cultural indicators comprised the presence of tikanga, the spiritual relevance of the area, and the strength of Maori identity and oral history based on the quality of the area. Tikanga was a primary food source for the local Maori before the drainage scheme, providing an abundance of eels from the Tarawera and Rangitaiki Rivers. After the drainage scheme, the food supply was completely cut off, and the lagoon has never since been a source of tikanga for the locals. The spiritual relevance mainly refers to the wahitapu (sacred lands) near the lagoon where warriors who fought in the Kaokaoroa battle are buried. During the debris flow, the remains of Maori ancestors were transported from their original burial grounds, thus detracting from their cultural mauri. However, the excavation and remediation projects have enabled the remains to be reinstated in their rightful locations. The identity factor alludes to the Maori legend of the wheke (octopus), which gives a cultural reasoning for why the rivers of the Rangitaiki Plains were situated in such a winding pattern with a large estuary at the seashore. After the drainage scheme, this legend no longer held true, since the rivers were cut off from Te Awa o Te Atua.

Social indicators encompassed the aesthetic quality of Te Awa o Te Atua, the use of the area as a public amenity, and as a facilitator for transportation. Before the plains were drained, the estuary was commonly used by locals as a recreational area for swimming and other activities; but once the rivers were cut off from the estuary, the stagnant waters were no longer an ideal location for recreation. Furthermore, the estuary could no longer provide a means for canoeists to make their way to the interior of the plains via the Rangitaiki River. This limited the movement of people and goods within the Western Bay of Plenty. Finally, It was acknowledged that qualifying the aesthetic quality of Te Awa o Te Atua was highly subjective, since values were based on pictures from the respective time periods and the assumption that the estuary was of the highest aesthetic quality prior to human involvement.

Economic indicators for the assessment included that of the local economy, the local employment, and management/infrastructure operations. The local economy was based on the fiscal contributions from fishing, transport, and the old Matata port. Economic inputs also came from the agricultural industry on the Rangitaiki Plains that arose following the drainage scheme. Local employment was measured by jobs available at the port, those on the Rangitaiki Plains farms, and the temporary jobs associated with the debris flow repairs and the wetland remediation plans for the lagoon. Management and infrastructure operations include the restoration of Te Awa o Te Atua after the debris flow and during the present-day wetland remediation project.

After selecting the indicators, a value on a scale of +2 to -2 was given to each indicator for each of four different time periods: pre-drainage in the 1900s, post-drainage in 1925, post-debris flow in 2005, and post-remediation in the present day. A value of +2 indicates that the mauri is completely restored and/or at its original state of health. A value of -2 indicates that the mauri is depleted. A value of 0 is given if there was no change in mauri since the previous time period, or if the indicator is irrelevant at that time period (Morgan 2006). Once each indicator is given mauri values for all four time periods, those values were averaged for each time period to obtain a balanced mauri value over the past hundred years. The previously stated mauri value descriptions also apply to the final mauri calculations. The Mauri Model values were placed into an excel spreadsheet chart, and the results were presented graphically.

RESULTS:

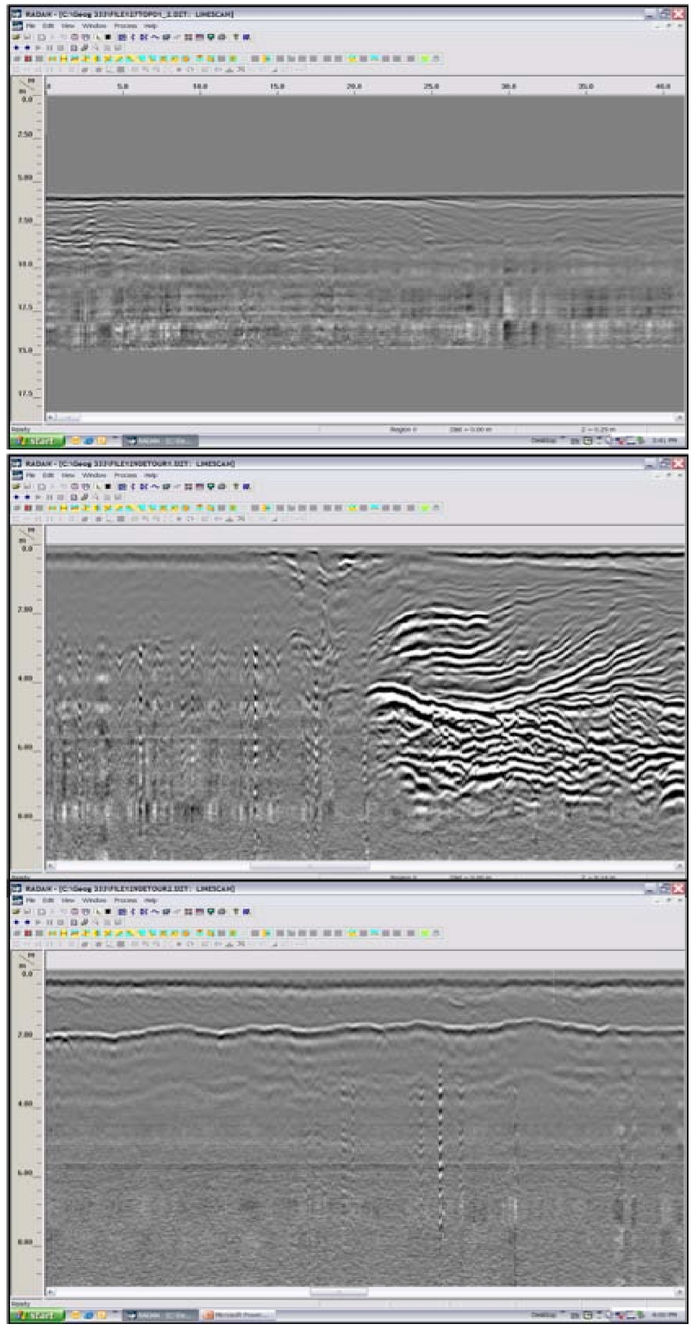

Figure 8: Main transect reading (top); perpendicular detour reading with dune faces (middle); parallel detour reading with water table.

Upon finishing the analysis of the GPR data using Radan, the results showed no sign of a debris flood unit. The only visible unit was the post-excavation man-made fill, which makes up the majority of the embankment (See Figure 8). The water table was not visible either, reinforcing the conclusion that the debris flood unit is not clearly delineated in the data, since the unit would have to be located below the water table (Dougherty 2009). It is evident that the antenna used for the data collection could have been stronger in order to see deeper into the subsurface; however, strengthening the antenna would lower the quality of the image. It is also important to keep in mind that, while the embankment was not an ideal location for the GPR transect, it was the only viable location to collect the data in such a limited area. The GPR readings from the two detour transects did hold some interesting features. The perpendicular transect, which extended north toward the shore, exhibited dune reflections in the subsurface. Alternatively, the parallel transect that skirted the northern bank of the lagoon showed a water table reflection surface (See Figure 9). Below the water table, a clay layer approximately two meters thick can be observed from the reading (Dougherty 2010).

Debris Flood Deposit

Without much information from the GPR, the remainder of the project was based on hand-auger data from the lagoon area. The calculated thickness averages from the fence diagrams agreed with the previously stated hypothesis. The northern and southern banks of the lagoon exhibited a slightly thinner horizon of debris flood material than the central transect. The northern transect was on average .73 meters thick, the central transect .92 meters, and the southern bank .84 meters. Between the three fence diagrams, the average thickness of the debris layer deposited in this part of the lagoon was approximately .83 meters. To determine the approximate volume of debris deposited in Te Awa o Te Atua and the surrounding areas, that value must be multiplied by the total area of the lagoon. Since the lagoon is about 200 meters wide by 1,050 meters long, or 210,000 m^2, the total volume of debris deposited during the flow event was approximately 174,300 m^3 of material.

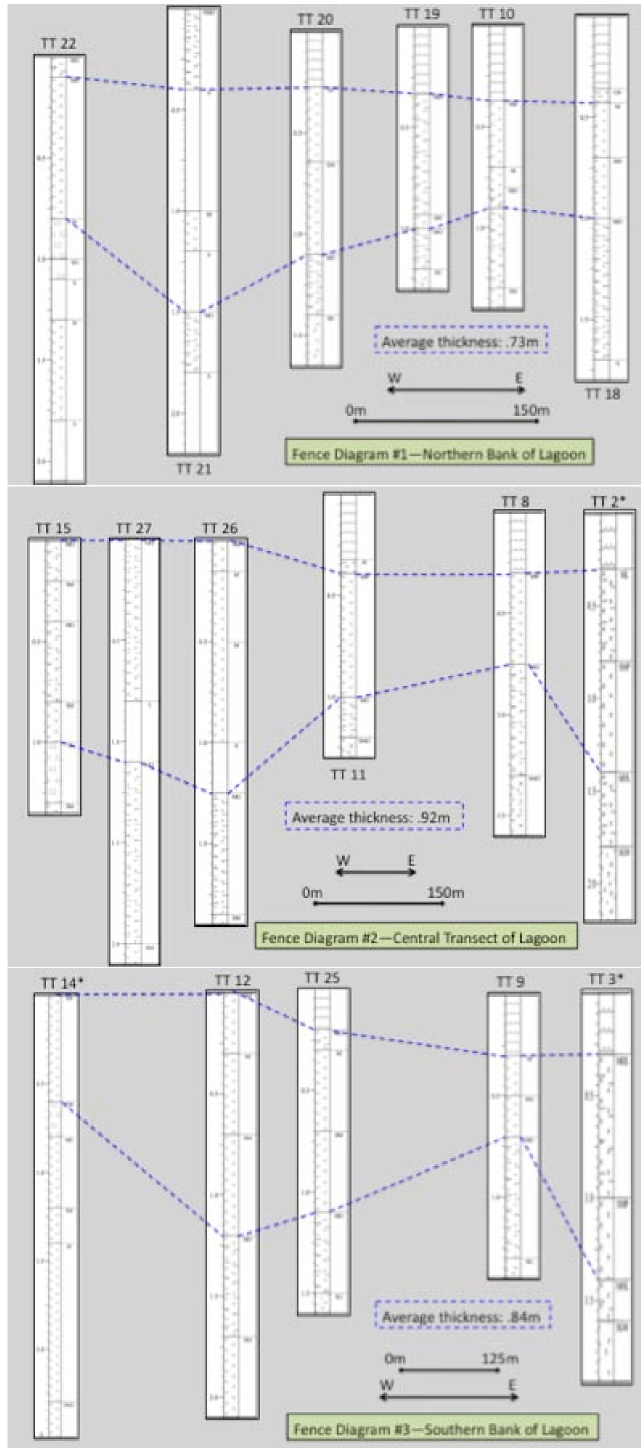

Figure 9: Fence diagrams for the northern (top), central (middle), and southern (bottom) transects of the lagoon.

Having examined the hand auger cores, one correlation was made with the GPR readings. The clay layer seen in the parallel detour reading (with water table surface) was visible in some of the logs, but not in all. Since the northern bank fence diagram transect is most closely associated with the location of the parallel detour used with the GPR, the borelogs from the northern transect were re-examined for the clay layer. As anticipated, two of the six logs contained a silt layer with plant remnants atop the debris layer material—concluded to be the ambiguous clay layer seen in the GPR reading (Dougherty 2010 pers. comm.).

Mauri

The raw data inputted into the Mauri Model can be viewed in the Appendix at the end of this report.

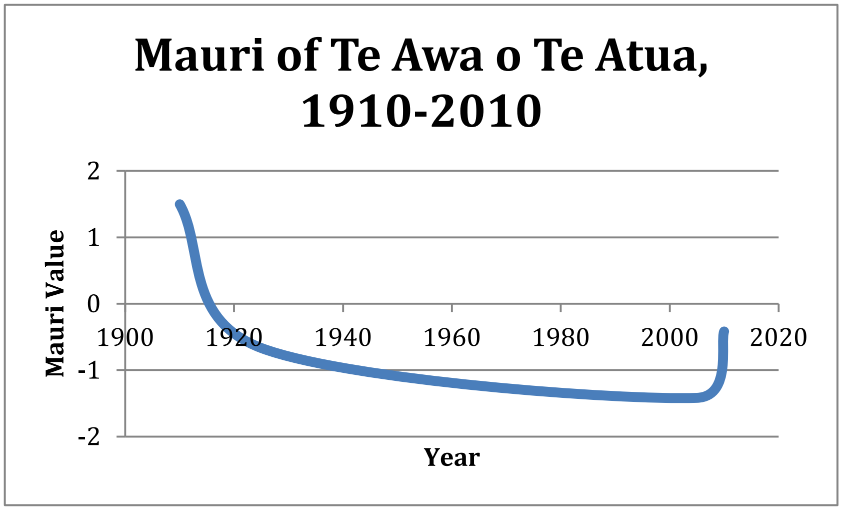

Figure 10: Graph of Te Awa o Te Atua's mauri evolution.

As seen by the graph in Figure 10, the mauri of Te Awa o Te Atua was strongest in the early 1900s, with a resounding mauri value of +1.5. That value plummeted to -0.67 during and after the drainage scheme was put into action. The mauri of the lagoon reached its lowest point following the debris flow, at a value of -1.42. However, efforts to repair the area following the debris flow have strengthened the lagoon's mauri to a value of -0.3 quite dramatically. Based on these results, it can be inferred that the mauri of Te Awa o Te Atua is still on the rise, since remediation projects are still underway.

DISCUSSION:

Debris Flood Deposit

The total debris volume result—174,300 m^3—is a very acceptable rough estimate, and agrees with previous research done in the area of Matata. If future studies were performed in the realm of the 2005 debris flow, a deeper GPR reading is recommended to correlate with the hand-auger cores taken in the lagoon. If a deeper GPR reading did not produce an image of an adequate resolution, locating an alternative transect location (that is not filled with excavated sediments) is also highly recommended. More GPR information from the subsurface would be beneficial to more accurately define the boundary of the debris flood layer. There is enough information to accept our current results, but incorporating more scientific techniques into a future study is strongly recommended.

Mauri

Based on the results from both the scientific and indigenous data, it is evident that both natural and anthropogenic events in the Matata region have had significant effects on the mauri of the lagoon. While the above graph makes it seem that a natural disaster like the 2005 debris flow incurred a more severe drop in the mauri of the lagoon, all assessments were arrived at based on a relative comparison from the original state of the estuary prior to the drainage scheme. For example, even though the debris flow reduced Te Awa o Te Atua's mauri to a -1.42, the previous drainage scheme had already brought the mauri down to a -0.67. The total mauri reduction caused by the drainage scheme alone was -2.17. The mauri reduction caused by the debris flow, however, was a mere -0.75. Thus, it can be inferred that the anthropogenically-induced changes to the environment in Matata were more detrimental than the naturally-induced changes. These results are quite logical, given previous knowledge that the Earth's natural processes have a harmonious fluctuation and balance. The Earth requires much more time to recover from human-induced changes, especially harmful ones.

Additionally, the wetland remediation project has indeed influenced the mauri of the lagoon positively. The total mauri inflation due to the wetland works is +1.12. Even though the mauri has been rising in the past few years, it has not reached a positive value. This brings up the delicate question concerning the objectives of the remediation: Was deciding to restore Te Awa o Te Atua to a wetland instead of its natural estuary habitat the best choice? According to the Mauri Model Assessment, Te Awa o Te Atua will never be able to return to its original mauri value of +1.5 because it will never be an estuary again. Nevertheless, it is important to consider which priorities come first for Te Awa o Te Atua, the maximum mauri, or the most economical and time-practical way to restore a natural habitat. For the present, the lagoon's mauri is continuing to rise through the remediation process, and will hopefully maintain a positive mauri value in the future.

Finally, the quantitative conclusion that anthropogenic changes to the environment have a more harmful effect than natural changes will be very useful for New Zealand's future sustainability choices. Perhaps in the future decision makers will consider using Dr. Kepa's Mauri Model prior to making any drastic decisions that might affect the mauri of the environment. Not only would such deliberation improve relations with the local Maori, but it would eliminate avoidable damages to the environment and possibly save a significant amount of money that would have been allocated for remediation.

CONCLUSIONS:

This topic is both interesting and important, as the research has provided information about natural debris flow hazards that have affected the town of Matata, while looking ahead to future debris flows and their consequent effects. The rough estimate of debris deposited in the western portion of Te Awa o Te Atua is approximately 174,300 m^3 of fine sands and silts. This result is indicative of the vast size and power of debris flow events. Their destructive potential to the mauri of the Earth is nearly as great as human-induced events, and as such should be prevented with much vigilance.

The Mauri Model results have shown that anthropogenic effects are more detrimental than natural events, thus reiterating the destructive power of humans on the planet. Therefore, extreme caution should be taken before making any significant decisions relating to the environment in New Zealand, especially in the Matata region. The knowledge gained from this project hopes to encourage the protection of Maori lands, particularly the Te Awa o Te Atua lagoon, so their mauri may be preserved and protected from natural and anthropogenic hazards in the future.

RESOURCES:

Bankoff, G. (2003): The Historical Geography of Disaster: 'Vulnerability' and 'Local Knowledge'. In G. Bankoff, G. Frerks, and D. Hilhorst (editors) *Mapping Vulnerability. Disasters, Development & People.* Earthscan, United Kingdom.

Brown, Keri (2006). *Traditional environmental knowledge in Aotearoa: A qualitative enquiry into the connection and significance of waahi tapu and the Matata flood.* University of Auckland, Geography 590-Directed Study Thesis.

Dempsey, Barbara (2005). "Awatariki Stream and Lagoon Works." Whakatane District Council. http://www.whakatane.govt.nz/Services/Hazard-Mitigation/Matata-Regeneration-Project1/Awatarariki-Stream-and-Lagoon.

Department of Conservation/DOC (2008). "Freshwater Wetlands: Matata (Te Awa o Te Atua) Wildlife Refuge Reserve." *Draft Bay of Plenty Conservation Management Strategy, 2008-2018*. Pgs 60-67.

Dougherty, Amy, Dr. Darren Gravely, and Dr. Dan Hikuroa (2009). *Surf and Turf: A study of a Holocene prograding dune system using ground penetrating radar, vibra-core, and total station surveying techniques.* Frontiers Abroad Earth System Science Curriculum Guide.

Gibbons, W.H. (1990): *The Rangitaiki 1890-1990*. Whakatane and District Historical Society, New Zealand.

Kjerfve, Bjorn (1994). *Coastal Lagoons*. Elsevier Oceanography Series, 60.

Marsden, M. (1992). *Kaitiakitanga: A Definitive Introduction to the Holistic World View of the Maori*.

McSaveney, M.J., R.D. Beetham and G.S. Leonard, (2005): *The 18 May Matata Debris Flow*

Disaster at Matata: Causes and Mitigation Suggestions. Institute of Geological and Nuclear Science Limited, New Zealand.

Morgan, T.K.K.B., (2006): *Decision-support tools and the indigenous paradigm.* Engineering Sustainability 159, Issues ES4. (169-177).

Wyatt, D.E., and T.J. Temples, (1995): *Ground-penetrating radar detection of small-scale channels, joints and faults in the unconsolidated sediments of the Atlantic Coastal Plain*. Environmental Geology 27: 219-225.

FIGURE REFERENCES:

New Zealand Accommodation Online, http://www.nzaccommodationonline.com/new_zealand/map/index.jsp?showMap=BayOfPlenty.

New Zealand Aerial Mapping Ltd. Photo taken on March 17, 1987.

Tonkin & Taylor: Environmental and Engineering Consultants. Matata Regeneration Works. Photos taken June 09, 2009.

The Waitangi Tribunal, "The Ngati Awa Raupatu Report". http://www.waitangi-tribunal.govt.nz/reports/viewchapter.asp?reportID=a949cd08-4825-48bf-b038-fac923793297&chapter=10.

<u>**APPENDIX:**</u>

Mauri Model Raw Data

	Indicators	Pre-drainage	Post-drainage	Post-debris flow	Post-remediation
Environmental	Ecosystem (estuary)	2	-2	-2	-2
	Anthropogenic waste	0	-1	-1	-1
	Sedimentation	2	-1	-2	-1
Cultural	Tikanga (food basket)	2	-2	-2	-1
	Spiritual Relevance	2	2	-1	1
	Identity (wheke)	2	-2	-2	-2
Social	Public amenity	1	-1	-2	0
	Transport	2	-1	-2	-1
	Aesthetic value	2	-1	-2	1
Economic	Local economy	2	-1	-1	-1
	Local employment	1	1	1	1
	Management and infrastructure operation	0	1	-1	1
	Year (approx)	1910	1925	2005	2010
	Total Mauri	1.5	-0.6666667	-1.416666667	-0.416666667