COMPARATIVE ASSESSMENT OF GAUGED AND OBSERVED CALIBRATION DATA

Tristan Jamieson: Watershed Consultation Ltd

ABSTRACT

Stormwater modelling assessments, and the resulting conceptual flood alleviation designs, are typically hampered by the lack of available calibration and verification data. This is, in part, due to assessment criteria (often 5 -100yrs ARI) being significantly greater than the period of monitored flow data, but even when flow records are of sufficient length, the catchment hydrology (at least in urban areas) has undergone such radical change that the data is no longer valid. At best we are often left to rely on anecdotal information such as historical records of complaints and observed flooding.

This paper utilizes the long term and detailed monitoring network set up as part of the Hikurangi Flood Control Scheme to assess the limitations of substituting anecdotal and qualitative data for detailed monitoring.

The Scheme, which is approximately 2 km in length, has continuous inflow and outflow records spanning 50 years (at 15 min intervals). In addition to this there is over 10 years of continuous and simultaneous monitoring at 8 locations within the scheme. The scheme stake holders are directly and in some cases severely affected by its ability to control flood waters. As a consequence there is an even greater amount of highly usable observational information.

KEYWORDS

Anecdotal Flooding Data, Water Level Monitoring, Comparative Analysis

1 INTRODUCTION

This paper utilizes the long term and detailed monitoring network set up as part of the Hikurangi Flood Control Scheme to assess the limitations of substituting anecdotal and qualitative data for detailed monitoring.

The Hikurangi scheme is of particular interest, not only because of the significant amount of observational information that has been collected, but also because of the sensitivity of the scheme's operation to changes in water level. The anecdotal data must be at least as accurate as the monitoring data for it to be useful, as the tolerances for the operation of the scheme are in many cases at the level of accuracy of the monitoring network.

The scheme operates such that stakeholders receive (on average) a predefined proportion of the floodwaters. Receiving the water is counterproductive to the operation of their farms, and water not apportioned correctly to one property owner will most likely result in another's having a disproportionate amount of inundation.

The size of the scheme is such that accurately measuring the volume of water apportioned to each farmer is not practical. Hence, developing an understanding of how each flood affects each stakeholder is a matter of collating the vast amount of observational and monitored data and undertaking detailed hydraulic assessment.

2 HISTORY OF THE SCHEME

The Hikurangi Swamp Scheme was constructed during the early 1970's as a flood relief scheme to benefit and improve some 5,634 hectares of low-lying and flood prone agricultural land. Prior to the existence of the scheme the land was generally of marginal use with the bulk of agricultural operations occurring around the fringes. The introduction of the scheme has allowed the land to become highly productive from an original position of very low productivity.

Following the scheme's introduction by the Catchment Commission the performance was monitored and a number of changes were made to the operation. Subsequent significant rainfall events during the 1980's and 1990's also resulted in further ad-hoc adjustment of the scheme both by the controlling authority and by individual landowners to such an extent that the performance and fairness of distribution of flood waters to the individual scheme stake holders had become uncertain.

Following this, Whangarei District Council undertook a hydraulic review of the scheme's performance in 2004. The hydraulic performance review appeared to indicate that the scheme was not functioning as originally intended – most likely as a result of spillway amendments but also potentially as a result of changes in the type of rainfall events manifesting flood conditions (shorter durations). Ongoing debate about the validity of the scheme assessment resulted in periodic reviews of the hydraulic assessment until a resolution was achieved during the consent hearing process in 2010.

2.1 Outline Description of the Scheme

The Hikurangi Swamp Scheme is located north west of Whangarei and spans the confluence of the Waiotu and Whakapara Rivers while being drained by the Wairua River. In addition to these there are a number of smaller tributaries which also contribute to the scheme either through gravity (during low flow in the main channel) or through pumping stations during a high flow regime.

The major scheme elements (the river flood control banks and associated channel straightening and pump stations) effectively extend from State Highway 1 at the northern end (where it crosses the two rivers) to the Lewis Bridge at the southern end where it crosses the Wairua. Figure 1 shows the approximate extent of the lowland section of the scheme, pump station locations and stop bank spillway positions.

Figure 1 Extent of Flooding Scheme

The Whakapara and Waiotu Rivers combine at the Junction "pocket" to form the Wairua River which continues approximately southwards through the upper portion of the scheme for approximately 5.5km to Jordan Bridge and then in a generally south westerly direction for a further 5km to the Lewis Bridge at the effective downstream limit of the scheme. A significant tributary, the Mangahahuru Stream, joins the Wairua River approximately half way between the Jordan and Lewis Bridges.

The provision of control banks affords limited flood protection to the adjacent farm land, which is divided into seven "pockets" that receive and discharge (when flood protection is exceeded) flood waters independently of one another. The pockets are segregated by further stop banks and natural land features.

2.2 SCHEME DESIGN PHILOSOPHY

The scheme fundamentally affords limited flood protection to low-lying, highly productive farmland by constraining the flows of the Whakapara and Waiotu rivers and the Mangahahuru Stream within stop banks. This allows increased depths (and volume) of flow without causing flooding of the adjacent land. Runoff from the low-lying land and the adjacent, contributory elevated hills are discharged through gravity doors during periods of low flow levels in the rivers and are pumped out during elevated river periods.

In rainfall events, where the main river levels approach the point of exceeding the main stop bank levels, flood waters are discharged (overspilled) into the adjacent low-lying farmland through designated spillways formed as controlled low points in the main stop banks. In order to maintain the fair flooding of land the spillways were designed to distribute floodwaters into each of the seven scheme "pockets" in the same volume proportions as if the scheme did not exist. The design distribution portions are set out in Table 1 below:

Table 1 Pocket Flood Volume Distribution

Scheme Pocket	Low land Land Area	Design Flood Volume %
Pocket 1	275 ha	5
Pocket 2	919 ha	20
Pocket 3	190 ha	3
Pocket 4	1182 ha	25
Pocket 5	1619 ha	10
Pocket 6	506 ha	14
Pocket 7	943 ha	23

3 DATA COLLECTION FOR HYDRAULIC ASSESSMENT

At the time that the original hydraulic assessment was being prepared very little data was available concerning timing of river rise and fall, peak flow levels and likely overspill periods. The original assessment was heavily reliant on NRC rating curve data from Northland Regional Council and their associated level recorders at the upstream limit and substantially downstream of the scheme. As a result of the early work (circa 1998) it was recommended that Whangarei District Council install water level recorders at intervals through the Wairua River within the bounds of the scheme. The location of these recorders is shown in Figure 2

Figure 2 Monitoring Locations – Water Level Recorders

3.1 WATER LEVEL MONITORING INSTRUMENTS

Water level monitoring within the swamp was undertaken using a network of pressure transducers. A pressure transducer can measure the temporal variation in the hydrostatic water column. The system includes a vent tube for automatic compensation of the variations of the atmospheric pressure and a data logger which stores the recorded data ready for download.

As with any field monitoring program of extended duration, it is likely that some period of record will include poor or missing data. The following sections discuss the observed limitations of the monitoring network within the swamp scheme:

During normal flow conditions, the pressure sensors are located outside the primary channel. Consequently they observe a zero depth. For this reason it is difficult to identify that a sensor is not working until a flooding event has passed, and the failure can be observed in the logged data. Figure 3 shows a data logger failure at site 3 during a significant event.

This type of failure occurred on two occasions within the monitoring period. Each time a gauge failure was identified, a technician was mobilised to resolve the issue.

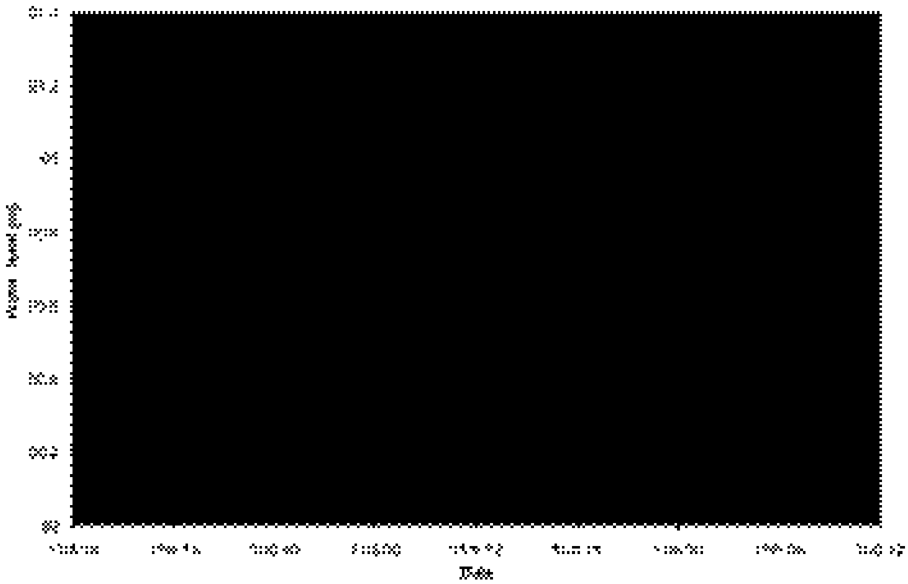

Figure 3 Comparison of failed data logger recorded data with expected hydrograph

Not even the most accurate pressure instruments will hold their accuracy indefinitely; they are all prone to drift over time. Any device that is constructed to measure pressure is going to have some complexity in its construction incorporating an assortment of materials with different physical properties. When exposed to many pressure and temperature cycles these materials will expand and contract and drift by varying degrees from their original state. This drift will result in inaccuracies in the monitoring network, which will increase as the monitoring period progresses. Drift can occur either as uniform offset throughout the range of pressures measured, or can vary throughout the range of pressures experienced by the sensor.

On two occasions during the monitoring program the sensors were tested for drift by exposing them in the field to known pressures. On both occasions all the monitors were observed to be within the range of instrument accuracy expected.

A pressure transducer is only capable of measuring the depth of the water column directly above it. As a result the elevation of the sensor needs to be levelled in order that the water depth can be related to a water level. While this in most instances is not difficult, the isolated locations of the sensors within the monitoring scheme set up for the Hikurangi Swamp, would undoubtedly have some impact on the accuracy of the sensor levels. Additionally any movement in either the structures supporting the sensors, or the sensors themselves, would cause an incorrect water level recording. Movement was considered to be a significant concern in this specific application due to the potential interference from stock. The elevation of each transducer was surveyed on 4 occasions through out the monitoring programme. This first survey was during installation, and undertaken using GPS, this survey (the Original RL Zero) showed the most variation from the others which were all part of a "closed loop" survey. As can been seen in Table 2 while there is some variation within the surveyed elevations of the transducers, there is nothing which indicated significant movement of the transducer.

Table 2 Survey Results for the Pressure Transducers

	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
Original RL Zero	90.031	89.457	88.132	88.484	86.566	88.540
Survey 1	90.117	89.527	88.083	88.521		88.554
Survey 2	90.111	89.523	88.082	88.523		88.538
Survey 3	90.120	89.510	88.070	88.510		88.550
Average	90.095	89.504	88.092	88.510	86.566	88.546
Max	90.120	89.527	88.132	88.523	86.566	88.554
Min	90.031	89.457	88.070	88.484	86.566	88.538
Difference	0.089	0.070	0.062	0.039	0.000	0.016

While the pressure transducer is able to log variation in the water column through time, each transducer is only capable of level at single location. In creating a network of transducers it is anticipated that the frequency of point source data collected along the length of the channel is sufficient to adequately identify any changes in water gradient through out the event. However, it is conceivable that in locations of high velocity and change in flow direction superposition may occur. This could result in water level readings, which may not necessarily be representative through the width of the channel. An assessment was made of potential superposition based on previously observed flows and channel geometry. This assessment concluded that superposition was an insignificant error within the swamp scheme.

In addition to the potential for failure, drift, physical movement, and survey error, the transducer has an innate accuracy or error margin associated with the recording. In the case of the particular transducers used, the estimated accuracy was ± 25mm which, (other than complete logger failure) results in the largest error associated with the water level measurement network.

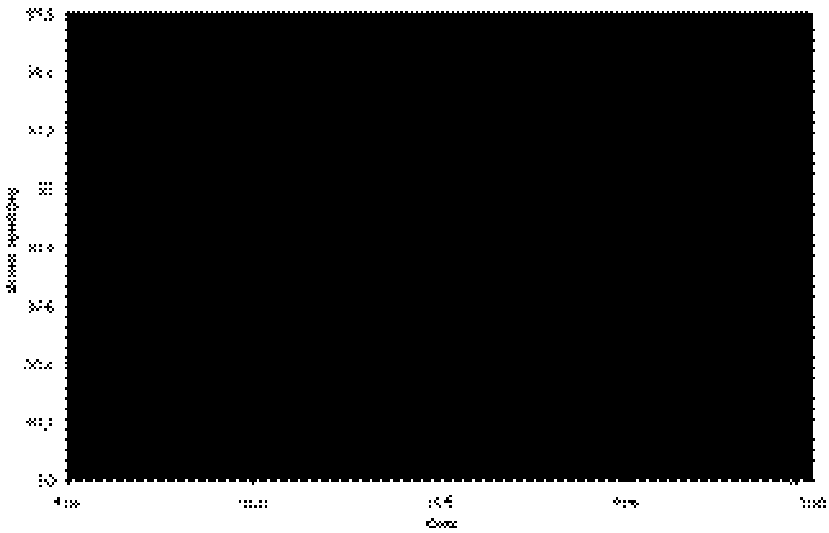

Figure 4 Example of water level data produced by a pressure transducer

3.2 ANECDOTAL AND OBSERVED DATA

Since the schemes inception, stakeholders and the various governing authorities of the time have tracked the operation of the scheme with an acute awareness of the need for verifying that it operates (on average) in a fair and reasonable manner. As in any natural system each event affects the scheme differently. This variation in the events is compounded by the size of the catchment and the fact that two large rivers (and many more smaller tributaries) confluence at the scheme. As a result there has been a significant amount of information recorded regarding the extent and nature of flood flows.

As with any observational information that is not independently documented (such as a photo) there is potential for inaccuracy associated with memory and/or a vested interest in a specific outcome. This is a form of error that has not been included for discussion in the paper.

STAGE PLATE READINGS

Manual stage readings form the longest data set within the swamp. Staging plates are located on channel side of each pumping station. Readings are taken either by the pump operator, or by farmers observing the flood. For the reading to be useful the observer is required to note down both the level and the time of the observation. Stage plates generally show increments of 100mm, the observer is required to interpolate a value based on the water level between the 100mm stages. This interpolation might result in an error of up to 30mm depending on the available light (many of the events peaked at night). In addition any wave action can cause the interpolation to be significantly more difficult, and prone to greater error. The pumping station is a concrete structure cutting through the flood control berms. It may well cause a disturbance to the flow during peak velocities, which could result in localised non-representative water levels. However this effect is likely to be relatively small given the low velocities within the scheme.

Figure 5 shows the staff gauge readings at a pumping station during a flooding event in 2000. This was a site where the observations were frequent, the observer visited the site 11 times during flooding event, however once the flood has peaked, and begins to recede, there are no more observations – leaving the nature of the recession unknown. There is only one point identifying that the recession has started, any inaccuracies in this final point would have a significant impact on the understanding of the duration of peak water level. The duration of peak water level is significant as it directly affects the duration of spilling. One reading (point no.7) appears to be erroneous. Despite its limitations this was considered to be very useful information. A majority of other pumping station readings were much more infrequent, and rarely captured the peak of the event.

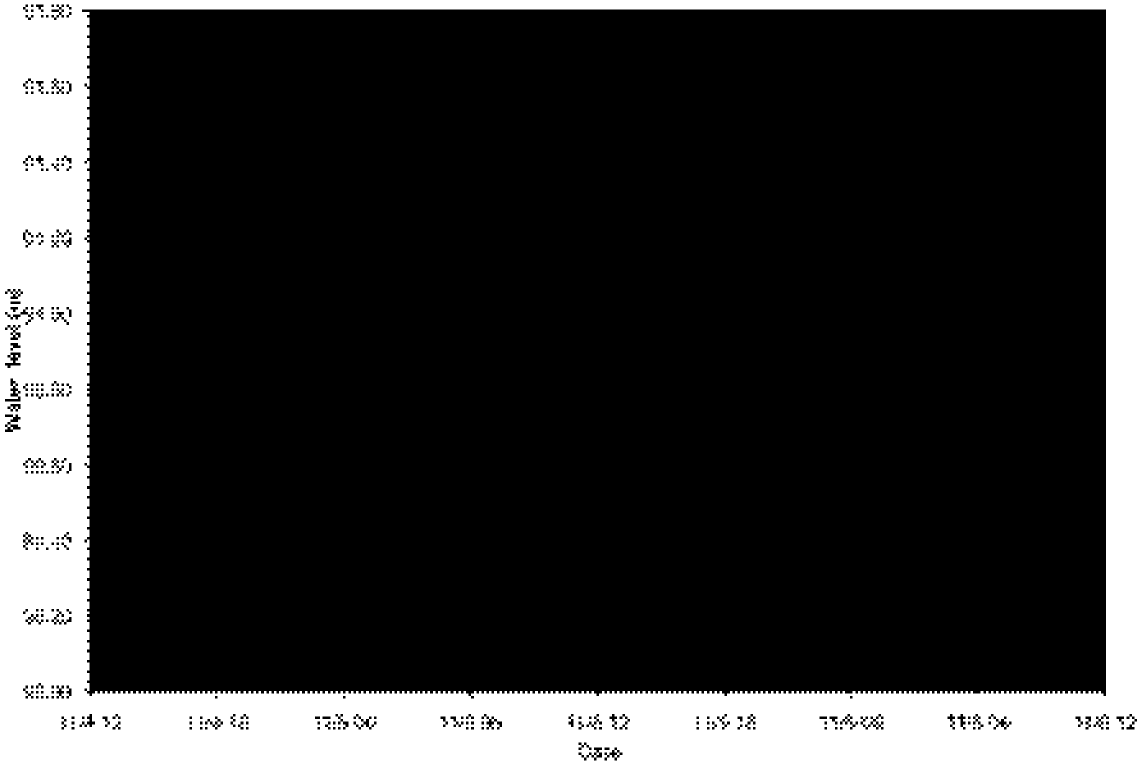

Figure 5 Water levels observed on a staff gauge at a pumping station

VOLUMETRIC CALCULATIONS

A volumetric assessment of floodplain inundation can be determined either by mapping the area of inundation or (assuming a zero hydraulic gradient) having a known water depth at point of known elevation. Either approach requires an area/stage curve for the flooded area. All the pockets in the Hikurangi Swamp have had detailed topographic surveys developed as part of the initial scheme implementation. These surveys have been used to develop area stage curves. Figure 6 shows a stage volume curve for a pocket within scheme. As with many floodplains the minimal variation in topography results in a relationship between depth and flooded volume, which is highly sensitive to depth reading error. In the particular case shown in Figure 6 an error in depth measurement of just 250mm would result in an error of flooded volume estimation of 106 m3. As shown in Figure 5 errors of up to 500mm have been observed from manual stage readings.

While the extent of inundation can be verified by other observations such as photographs and high water line/weed deposits the actual volume of interest is the amount spilt over the control bank. Other contributions to the volume of water in the pocket include the inflows from other catchments and rain falling directly in the inundated area – which effectively results in 100% runoff. There was no way of differentiating between this and the volume spilt over the control banks, and as such there is limited confidence in this data stream. Additionally it is conceivable that a number of pockets have a significant hydraulic grade when in flood. This hydraulic grade results from inflows continually contributing from the pocket's own catchments at the upper end and the discharge through the pumping station at the lower end (in some cases greater than $11m^3/s$). Other sources of error include missing the peak water level and recording the level at a different time to the peak.

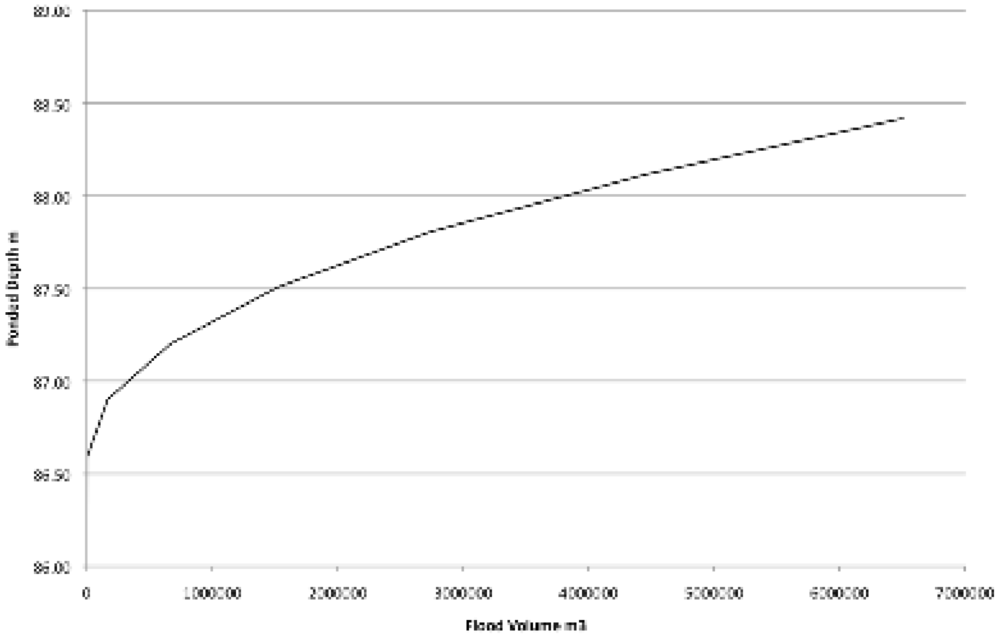

Figure 6 stage/volume curve for a specific "pocket"

DURATION OF SPILLING

In a flooding control scheme, which utilises stop banks, two variables of any given flood event dominate the inundation of a floodplain. These are:

1. The depth of water exceeding the stop bank crest; and,

2. The duration for which that depth is sustained.

Knowing the time and location which the spilling begins and ends gives valuable insight into the volume of water spilt, it also gives at least 2 points of water level data during the event. However, as a result of the inaccessible locations of many of the control banks, and the fact that spilling is of such a duration - that either the start or end of spilling often occur at night time, only limited direct observations were made.

An attempt was made to infer spilling duration from the water levels in the pockets as recorded at the pumping station stage plates. There are a number of inaccuracies associated with this:

1. As shown in Figure 6 a small change in the depth at the pumping station stage plate relates to a significant change in volume spilt over the crest of the control bank. Isolating the time at which the water level in the pockets stops rising from the manual readings on the stage plate would be difficult at best, and while this was attempted, it is considered to contain significant error.

2. In most cases the location of the spilling crest is a significant distance from the site of the pumping station. The resulting lag time between the cessation of spilling and cessation of water level rise at the pumping station could in some cases be up to half an hour.

3. In addition to the volume contribution to the pockets from the scheme there is also contribution from the pockets associated catchment – this will affect water level rise in the pocket, and could cause erroneous results when determining the point at which scheme spilling ceases.

4. It is not clear whether the pumping stations operate during the event. The logical approach would be that they do not, as pumping into the channel from a pocket,

while the channel is spilling into the pocket would contradict the philosophy the scheme, however there have been some reports of pumping station operation. If a pumping station is operating, this would impact of the rate of change in water level within the pocket resulting in errors when using this rate of change to estimate the time at which spilling stops.

HIGH WATER MARKS – WEED LINE

There are many areas of the scheme that are inaccessible during a flooding event. In addition to these areas, the size of the scheme makes it difficult for any one person to view all the locations of interest during any one event. In these locations data such as peak water levels were assumed to be consistent with weed and debris deposit. While weed deposits regularly form bands along the length of the control banks, there has been no quantifiable information regarding the accuracy of assuming that the top of the weed band correlates to the peak water level. In some instances the level of the weed deposition was 200mm less than what was logged at the same location by the pressure transducer. It was not possible to determine which data source was at fault.

MEASURES DEPTHS AT SPILL CRESTS

The cross sections of the spilling crests have been surveyed in detail a number of times. Attempts to measure the spilling depth in specific locations, and project this onto the cross section were made on one occasion. This observation gives two significant pieces of information:

1. The water level in the channel (by adding the depth at the crest to the crest level at the location of measurement)

2. The cross sectional area of spilling water – which can be used to estimate the flow rate over the crest at the time of measurement.

This information was considered to be extremely useful. However, due to the safety aspects of traversing the crests during a flooding event, and the isolated location of a number of the crests, this information was only collected on one occasion.

OBSERVATIONAL DATA

In addition to the specific forms of data discussed above there was a significant volume of observational data able to be used to "build up a picture" of each flooding event. This information included photographs of inundation, historical press releases, comments in the pumping station logs from the operators, flood lines drawn on buildings etc. This information was collated and used where possible to benefit and add confidence to the hydraulic assessment of the scheme.

3.3 DATA CONFLICT

As with almost any data set as large as has been developed for the Hikurangi Swamp Flooding Scheme, conflict occurred between data items. This section gives only a few selected examples of such conflicts.

Figure 7 shows the water level graph as recorded by a pressure transducer. The logger is adjacent to a spillway, which has an estimated of spill duration, based on manual water levels readings at the pumping station. The manual water stage plate reading predicted a spilling duration of 3.5 hours. By tracing the spillway crest level onto the logged pressure sensor an estimate of 8 hours was made.

Figure 8 shows the water level point data manually read from a stage plate on the channel side of a pumping station. This has been superimposed with an interpolated water level graph from up and down stream level recorders. The data read from the stage plate seems to compare well, however the peak of the event was clearly missed, and what was originally recorded as the maximum level (point 1) was actually almost 8 hours after the event had peaked. This event was particularly poor for manually recorded data and it is assumed that this is a result of the peak occurring around 2am in the morning.

Not all conflict was between manually observed data and the pressure transducer data. Figure 9 shows an instance where the manual stage plate "peak water level" readings at a down stream location are higher than the upstream ones. The line in Figure 9 is the best estimate of the actual peak water levels based on interpolation between data loggers. According to the manually recorded data the crest at the location would not have been overtopped. If the interpolated line is correct, then significant overtopping would have occurred.

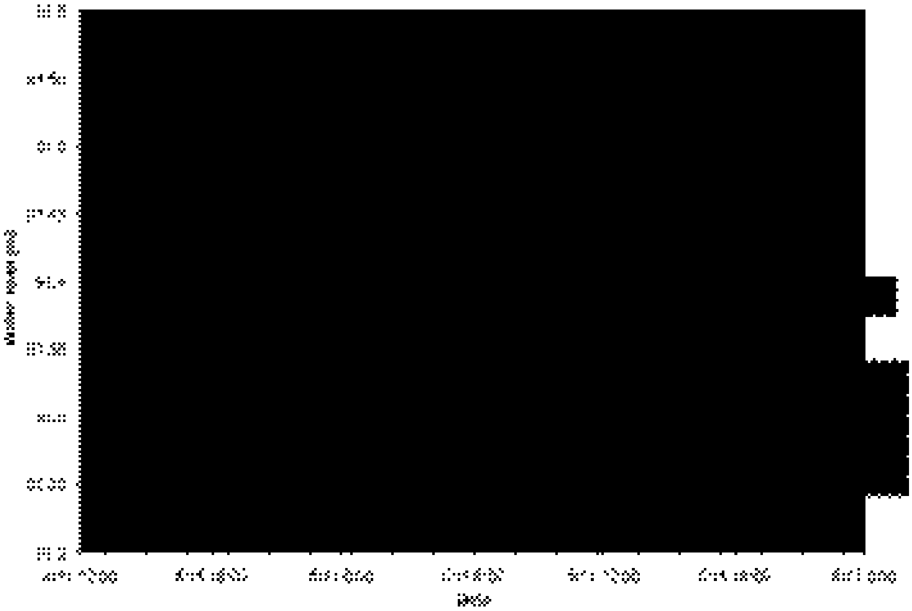

Figure 7 conflict in observed data – spilling duration

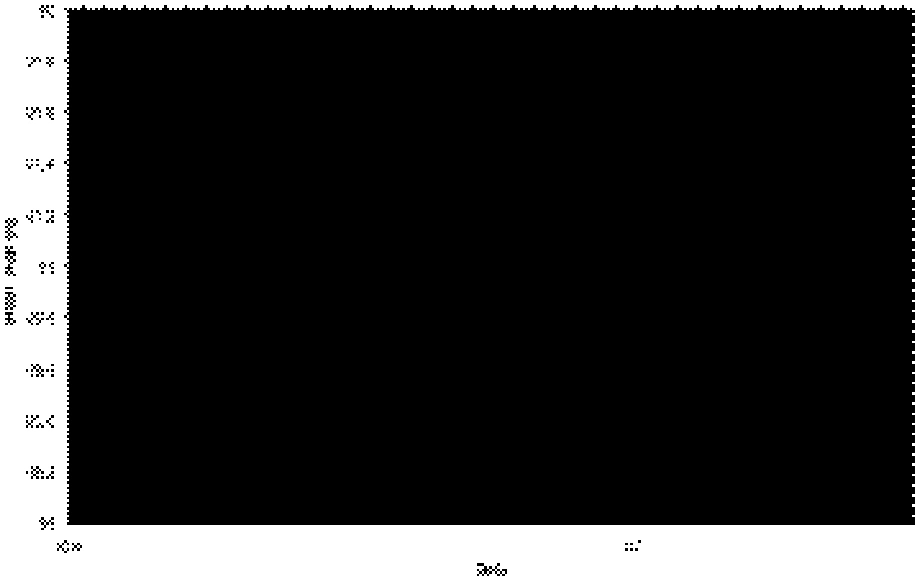

Figure 8 conflict in observed data – stage readings –

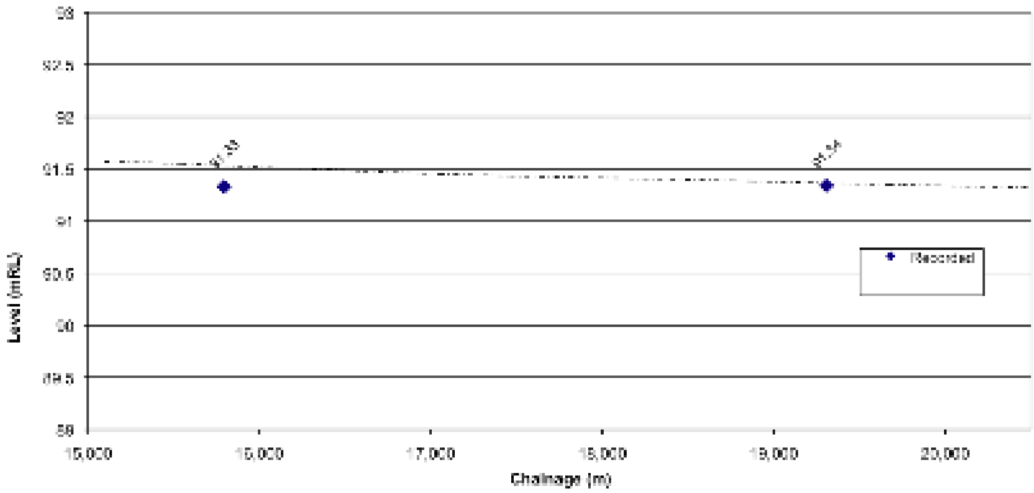

Figure 9 conflict in observed data – same data stream

4 CONCLUSIONS

In many situations, observed data is the only form of verification that the hydraulic engineer has available. And while this is invaluable there are some significant limitations to using observed data. The limitations of the data must be fully understood in terms of the specific study in order to appropriately use the data.

In the case of the Hikurangi Swamp Scheme where a variation of no more than 100mm in flood level within the channel can cause significant impacts to the stake holders, confidence in the data is of upmost importance.

While much of the observed flooding data proved to be rigorous and of high confidence, it was difficult, and in some cases impossible to verify this without the aid of the water level monitoring network that can been put in place.

For the observation data that was considered to be of low confidence it was again difficult to quantify this without having the water level monitoring network data to discredit it with.

In the situation where no historical automated data capture is available the engineer must scrutinise the observed data such that all the potential sources of error have been identified, and quantified. Only then can the data be used with any confidence for verification or calibration during a hydraulic assessment.

ACKNOWLEDGEMENTS

Conal Sumners - Stormwater Assets Engineer - WDC

James Blackburn – Director - Hawthorn Geddes Ltd

REFERENCES

"[Click here to Type References]"