Bay of Plenty Regional Council
31-Jul-2015

Analysis of Rainfall and Lysimeter Data

\\akl-fs.ursapac.local\akl-jobs\42075728\5 WIP\Report\Analysis of Rainfall and Lysimeter Data rev 4.docx
Revision – 31-Jul-2015
Prepared for – Bay of Plenty Regional Council – ABN: N/A

Analysis of Rainfall and Lysimeter Data

Client: Bay of Plenty Regional Council

ABN: N/A

Prepared by

AECOM Consulting Services (NZ) Ltd
8 Mahuhu Crescent, Auckland 1010, PO Box 4241 Shortland St, Auckland 1140, New Zealand
T +64 9 967 9200 F +64 9 967 9201 www.aecom.com

31-Jul-2015

Job No.: 42075728

AECOM in Australia and New Zealand is certified to the latest version of ISO9001, ISO14001, AS/NZS4801 and OHSAS18001.

Quality Information

Document	Analysis of Rainfall and Lysimeter Data
Ref	42075728
Date	31-Jul-2015
Prepared by	John Male
Reviewed by	Justine Bennett

Revision History

Revision	Revision Date	Details	Authorised	
			Name/Position	Signature
	31-Jul-2015	Report	Michael Summerhays Technical Director	

Table of Contents

List of Tables

List of Figures

1.0 Introduction

1.1 Background

The Bay of Plenty Regional Council (BOPRC) commissioned AECOM Consulting Services Ltd (AECOM), on 10th June 2015 to undertake an assessment of data from lysimeter sites across the region. BOPRC has seven lysimeter sites installed under pastoral land use across the region. The intent of these lysimeter installations is to;

- Quantify rainfall recharge of groundwater
- Guide the development of groundwater management policy, and
- Guide sustainable allocation and use of groundwater

1.2 Lysimeter sites

BOPRC has provided AECOM with data from five of the seven lysimeter sites for this assessment. The other two sites are recent installations and do not have sufficient record for analysis. The sites, the numbers of sensors, and the length and period of record are outlined in Table 1.

Table 1 Lysimeter Sites

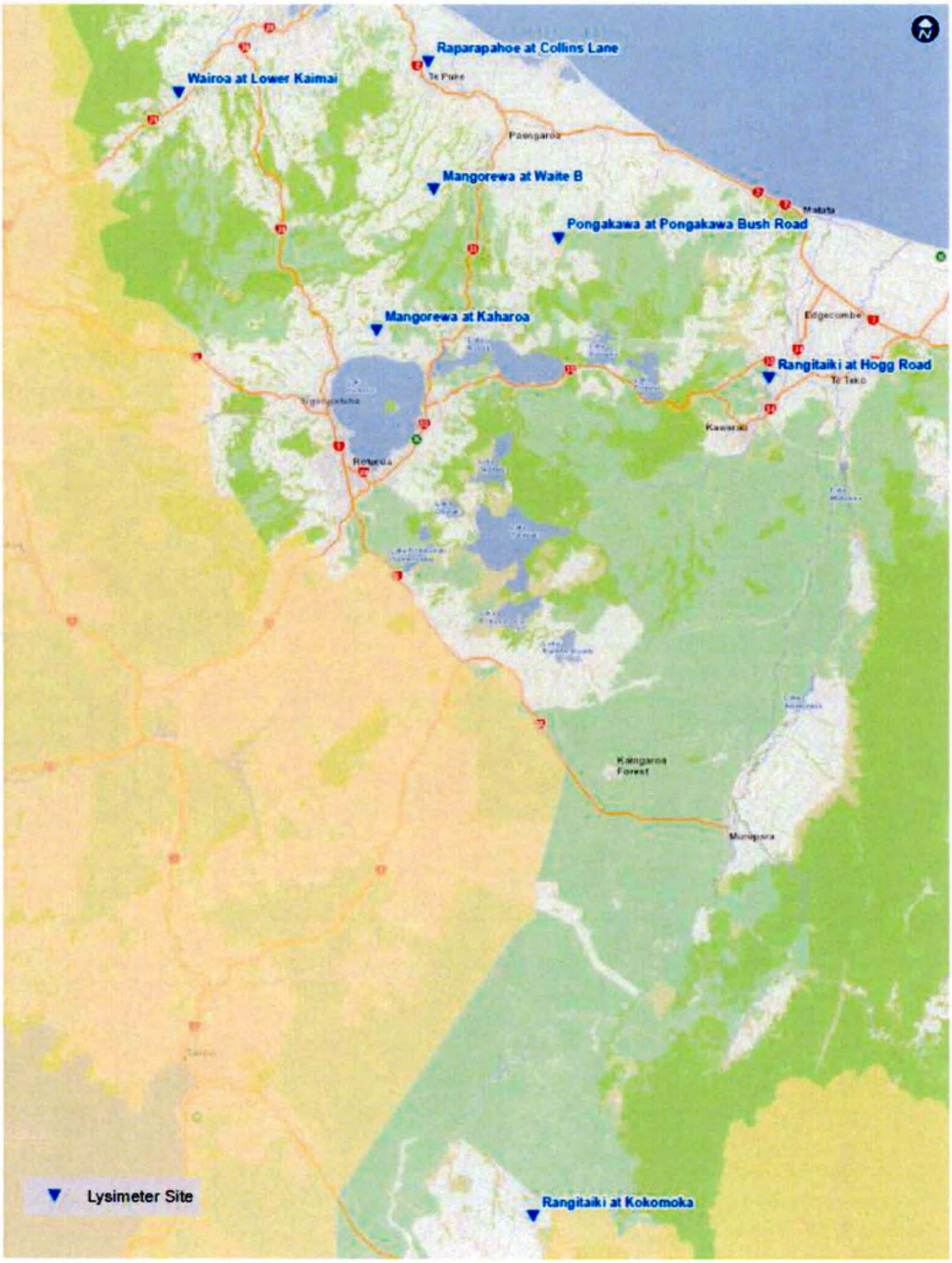
Site	# Raingauges	# Soil Moisture Sensors	# Lysimeters	Period of Record	Years of Record Assessed
Mangorewa at Kaharoa	1	1	2	26/10/2005 to 1/1/15	9
Mangorewa at Waite B	1	1	3	11/7/2013 to 1/1/15	2
Pongakawa at Pongakawa Bush Road	1	1	2	27/7/2010 to 1/1/15	4
Rangitaiki at Hogg Road	1	1	?		0
Rangitaiki at Kokomoka	1	1	3	23/10/2013 to 31/12/2014	1
Raparapahoe at Collins Lane	1	1	?		0
Wairoa at Lower Kaimai	1	1	3	18/3/2013 to 1/1/2015	1

The data has previously been reviewed once for Kaharoa. Now is an appropriate time to consider the data and the direction of the programme given the additional data that is available for Kaharoa, the data from Pongakawa, and the shorter data record from more recently established sites.

The data that BOPRC has provided has undergone quality checks by the BOPRC Environmental data team. No basic data gap filling or data manipulation has been undertaken by AECOM for this assessment.

The location of the sites is shown in Figure 1. The sites are spread across the region including one newer station in the headwaters of the Rangitaiki catchment. The rationale for site selection has not been shared with AECOM.

Figure 1 Lysimeter Site Locations



1.3 Lysimeter description

The installation and configuration of lysimeter sites is detailed in other BOPRC reports[1]. The basic design is a raingauge, soil moisture probe and two or three lysimeters at each site. The raingauge and the lysimeters are connected to tipping bucket collectors and record at 15 minute intervals.

The lysimeters are 500mm in diameter and 700mm deep. Their construction is described in BOPRC reports[2]

[1] *Groundwater Recharge at the Kaharoa Rainfall Recharge Site – Rotorua.* BOPRC Env. Pub. 2010/21

1.4 Scope of Assessment

The specific elements that are addressed in this work are;

- Analysis of the recharge component,
- Consideration of methodologies for the recharge analysis,
- Consideration of the relationship between recharge and climate variations/trends,
- Consideration of upscaling or regionalisation of results to a catchment level, and
- Evaluation of the existing and proposed lysimeter network

2.0 Assessment

2.1 Mangorewa at Kaharoa

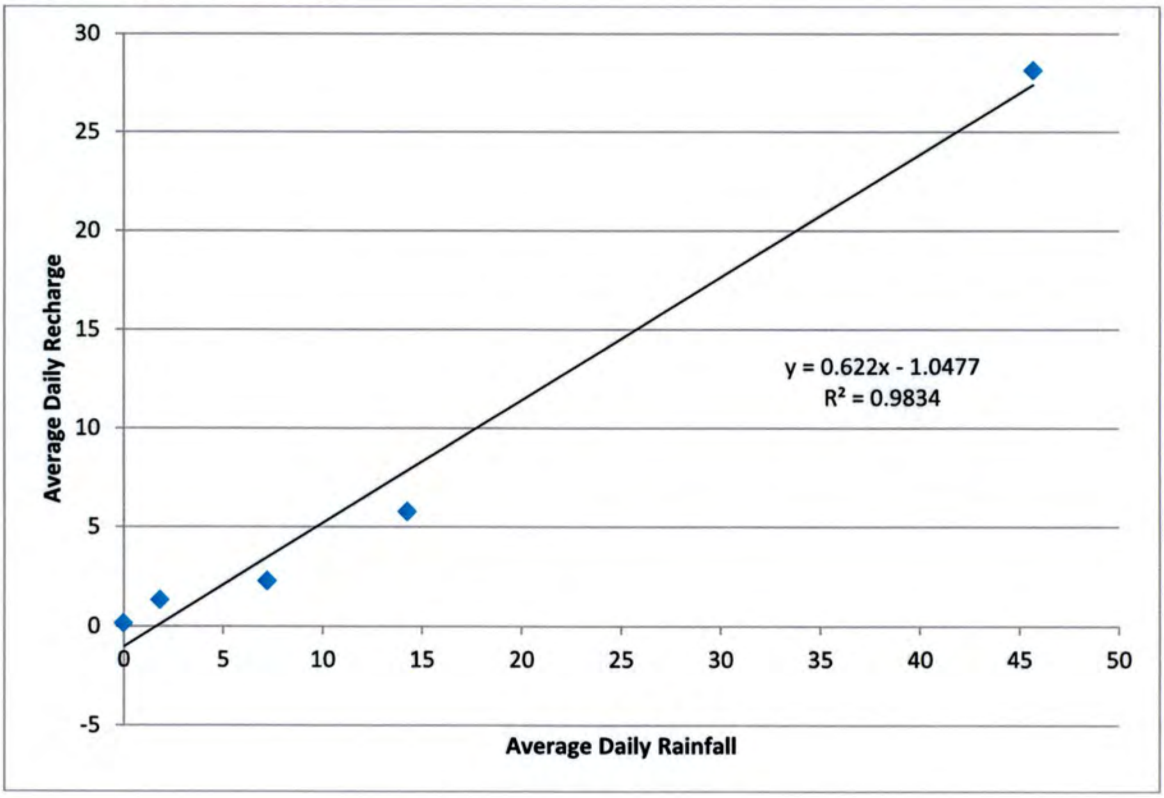
2.1.1 Daily

A breakdown of daily data shows that even on days with little or no rain there is ongoing drainage through the soil profile. As daily rainfall increases there is a greater daily recharge. This suggests that both rainfall and hydraulic processes in the soil profile influence recharge. The data is summarised in Table 2 and the relationship in Figure 2.

Table 2 Daily Rainfall and Recharge

Minimum Rainfall (mm)	Maximum Rainfall (mm)	Average Rainfall (mm)	Average Recharge (mm)
0	0	0	0.2
0.01	5	2	1.3
5.01	10	7	2.3
10.01	20	14	5.8
20.01	274.5	46	28.1

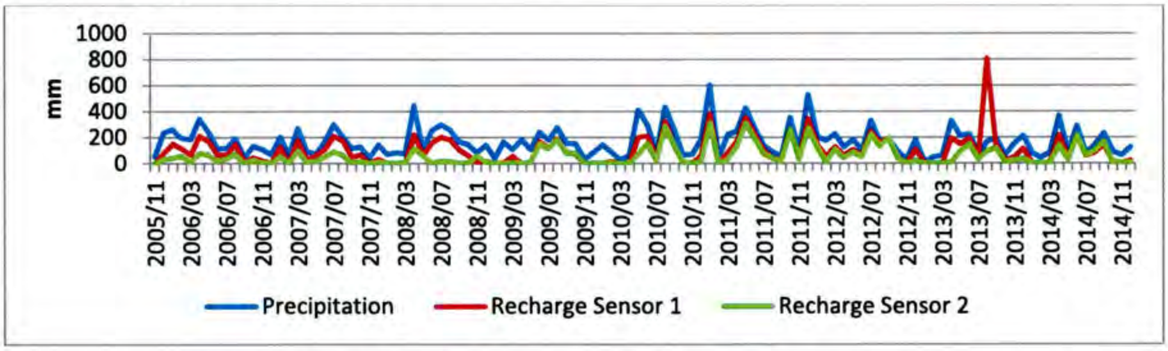
Figure 2 Daily Rainfall & Recharge



2.1.2 Monthly

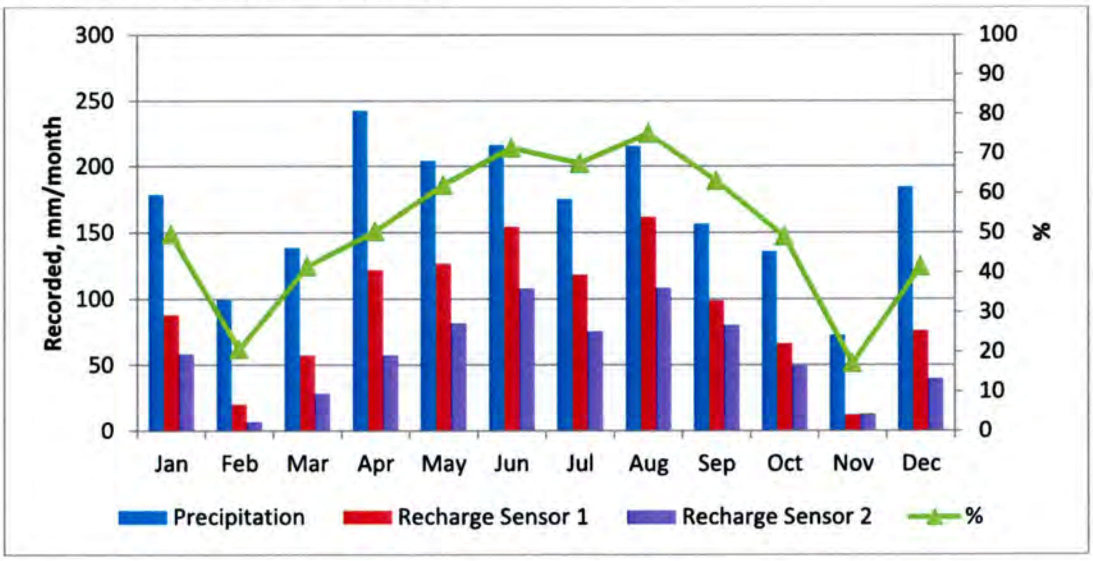
The monthly time series for rainfall and each lysimeter recharge sensor is plotted in Figure 3. There is a significant spike with 809mm of drainage at recharge sensor 1 during August 2013 that has no corresponding response in sensor 2. This needs to be confirmed by BOPRC as it may skew results of the assessment.

Figure 3 Monthly Rainfall and Recharge Series



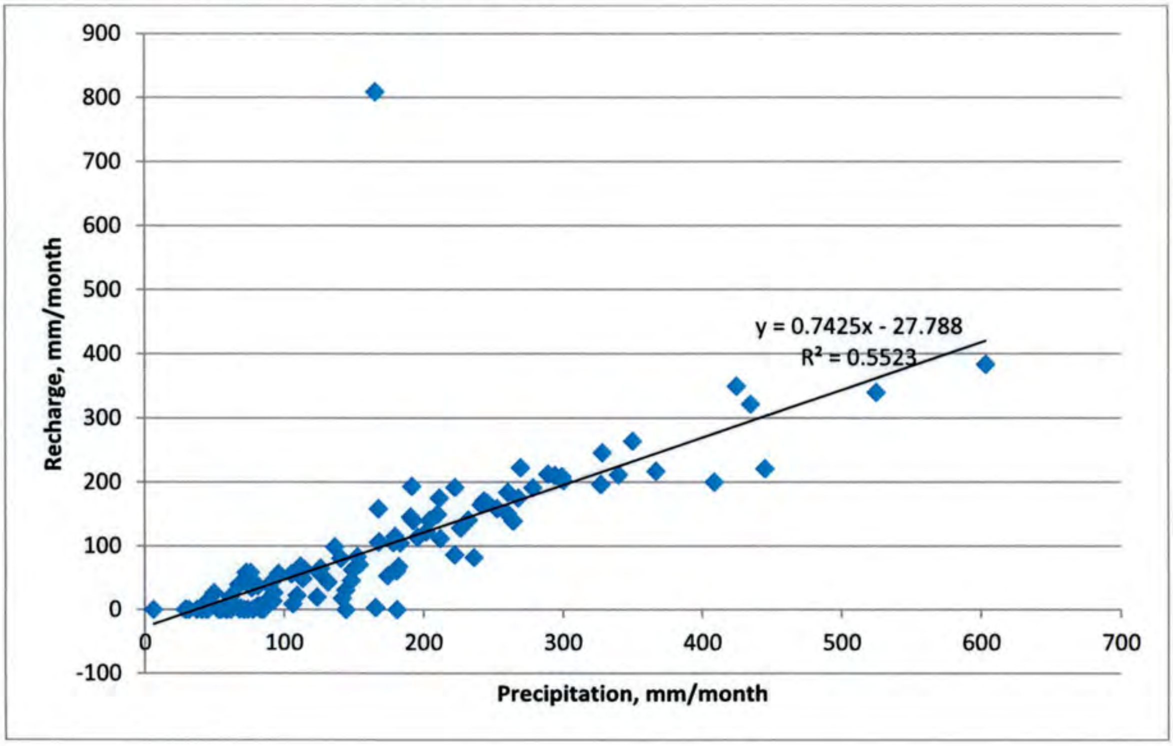
The average monthly data in Figure 4 shows a distinct seasonal pattern with the highest recharge during the winter months. Lowest recharge as a total and percentage occurs in November and February while for the period from April through to October the percentage of rainfall that recharges is greater than 50%, and up to 75% in August. However, of concern is the difference between sensor 1 and 2 in terms of the total recharge measured. This needs to be reviewed but it is a consistent pattern and because of that either reflects variability at the site of hydraulic properties or there has been an inconsistency in the setup of the lysimeter. Any photographs and installation notes require review to establish the cause of the pattern. Such a difference in recharge totals within such a small distance between sensors has implications for extrapolation of the data to catchment wide applications. In Section 3.0 the variability between sensors at one site compared to the variability between sites is considered in relation to regionalisation opportunities.

Figure 4 Average Monthly Rainfall and Recharge



The overall relationship between monthly rainfall and monthly recharge is shown in Figure 5. The outlier does not have a significant bearing on the relationship in this case because of the relatively large number of data points. The regression equation indicates that generally there is a threshold of approximately 30mm that has to be reached before recharge is initiated. This relationship is further considered in Section 3.0 where the data is combined to identify regionalisation opportunities.

Figure 5 Relationship between monthly rainfall and recharge



2.1.3 Seasonal

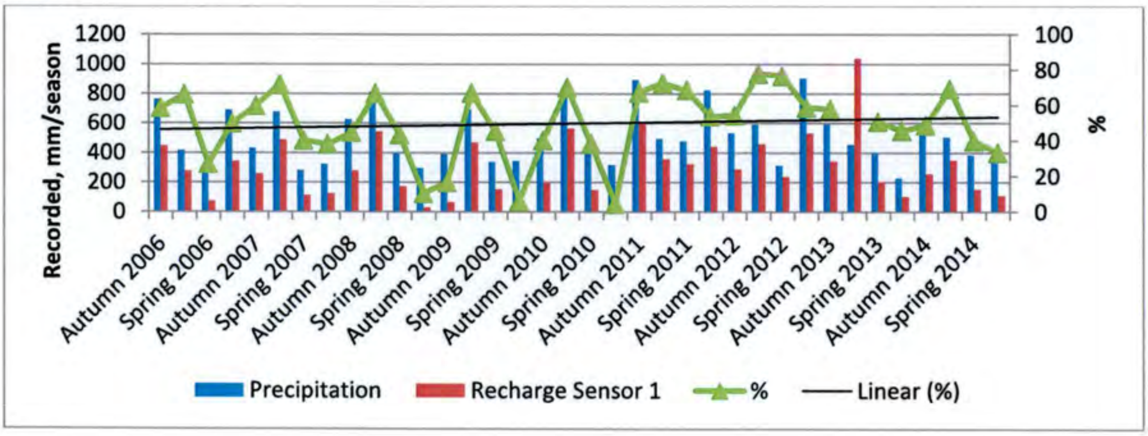
For this assessment the reporting of seasons is based on the accumulation of the following months;

- Summer – December, January and February
- Autumn – March, April and May
- Winter – June, July and August
- Spring – September, October and November

The seasons are the same for each site that has been assessed.

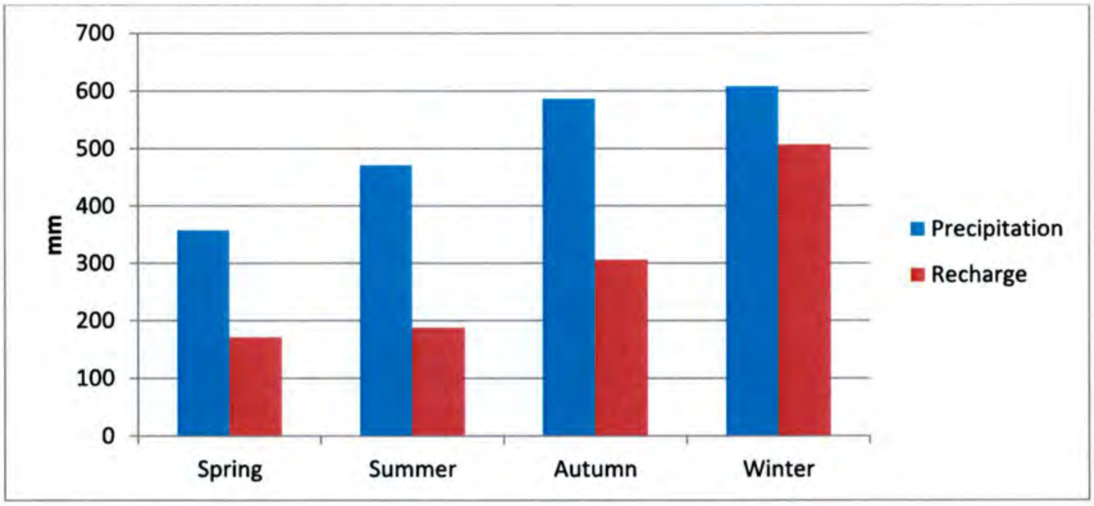
The seasonal cycle that has been addressed in 2.1.2 is shown for the length of record in Figure 6. The summer of 2010 had only 4% of the rainfall appearing as recharge while in the winter months ranged from the high 60's to nearly 80% of rainfall as recharge. Of note is the overall trend pattern which suggests nearly a 10% increase in recharge over the 9 years of record. This trend may be real or it could be stabilisation of the soil within the lysimeter. However, the soil stabilisation factor is not likely to have continued for such a length of time because of the soil column being cut in situ into the lysimeter rather than being comprised of repacked soil. Any finite conclusions cannot be established due to the short record period.

Figure 6 Seasonal Pattern



Average seasonal distribution of rainfall and recharge is shown in Figure 7 with the highest recharge occurring in the winter months.

Figure 7 Average Seasonal Rainfall and Recharge



2.1.4 Annual

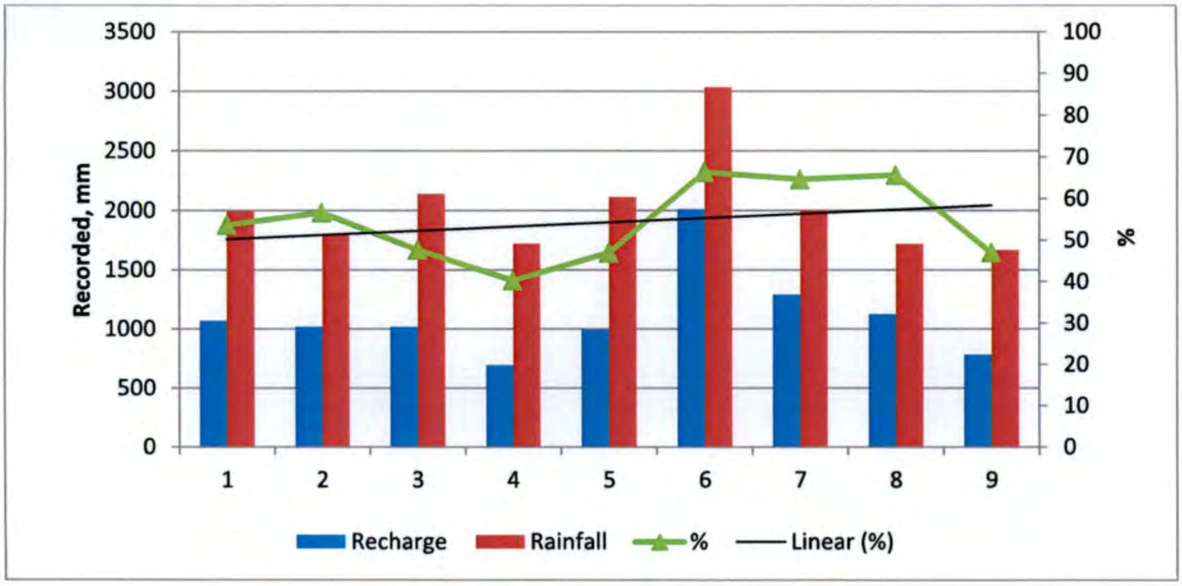
Annual recharge ranges from 40% to 66% of annual rainfall and averages 54% as shown in Table 3. Average recharge is 1112mm per year.

Table 3 Annual rainfall and recharge

Year	Rainfall	Recharge	Recharge Percentage
2006	1995	1070	54
2007	1799	1018	57
2008	2139	1018	48
2009	1722	694	40
2010	2112	991	47
2011	3036	2014	66
2012	2001	1292	65
2013	1720	1128	66
2014	1669	784	47
Average	2021	1112	54

The annual variability and the trend in recharge is shown in Figure 8. There would appear to be a cycle over a number of years that has occurred but the overall trend line is for an increasing proportion of rainfall as recharge. The length of record is too short to come to any firm conclusion about long term cycles in recharge volumes other than from a visual observation of the graph.

Figure 8 Annual rainfall and recharge



2.2 Mangorewa at Waite B

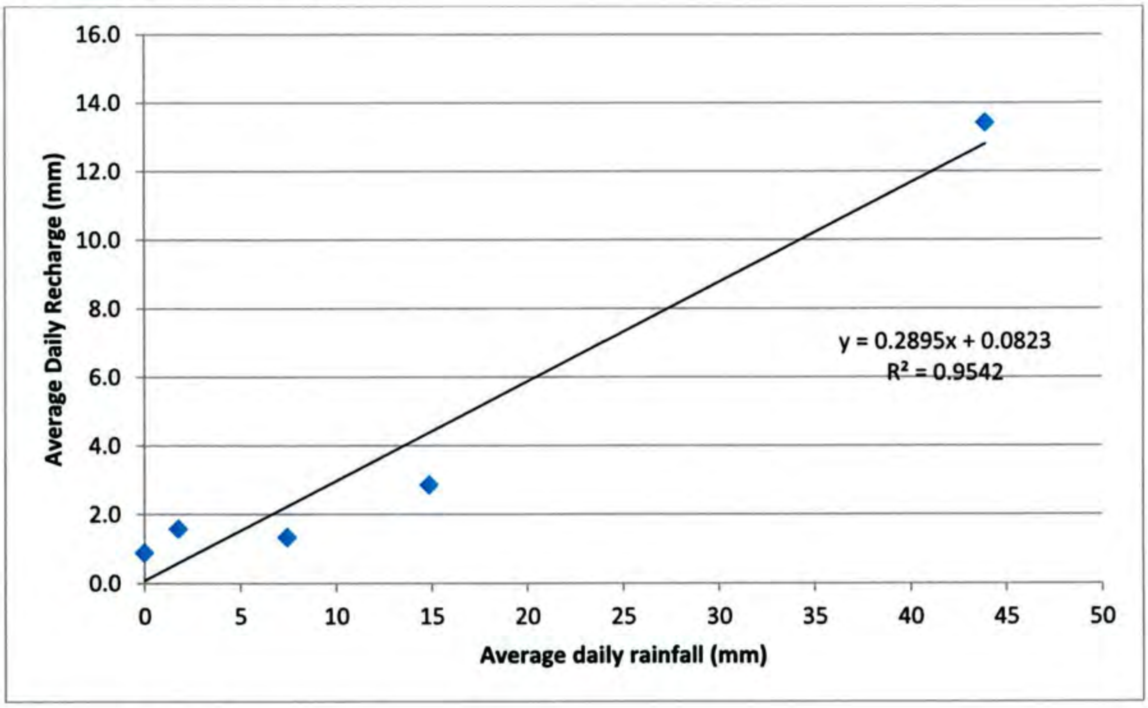
2.2.1 Daily

This site has only 2 years of record and so the extent of any assessment is limited by the length of record. A breakdown of daily data shows that even on days with little or no rain there is ongoing drainage through the soil profile. As daily rainfall increases there is a greater daily recharge. This confirms that both rainfall and hydraulic processes in the soil profile influence recharge. The data is summarised in Table 4 and the relationship in Figure 9. The average recharge by rainfall class is very similar to the Kaharoa site recharge. This may reflect the similar soil water holding capacity at both sites.

Table 4 Daily Rainfall and Recharge

Minimum Rainfall (mm)	Maximum Rainfall (mm)	Average Rainfall (mm)	Average Recharge (mm)
0	0	0	0.9
0.01	5	2	1.6
5.01	10	7	1.3
10.01	20	15	2.9
20.01	153.7	44	13.4

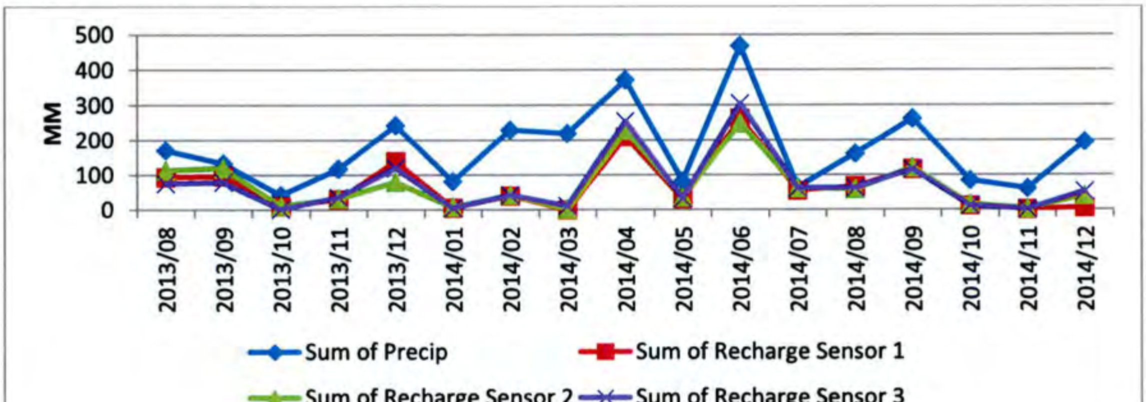
Figure 9 Daily Rainfall & Recharge



2.2.2 Monthly

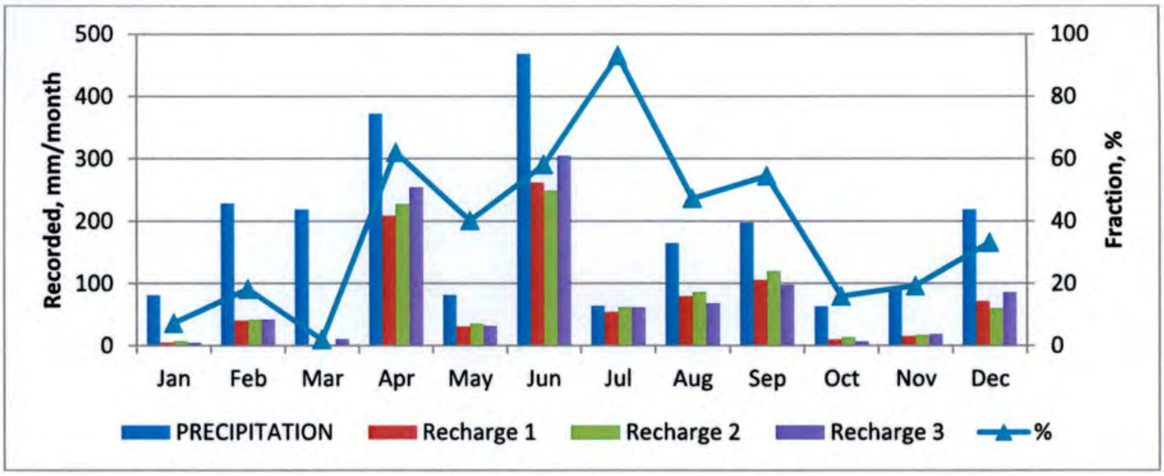
The monthly time series for rainfall and each lysimeter recharge is plotted in Figure 10 for the latter part of 2013 and 2014. Recharge is similar at all three sensors. For the most part recharge and rainfall follow the same pattern except the recharge from rainfall in February and March 2014 appears to be proportionately less

Figure 10 Monthly Rainfall and Recharge Series



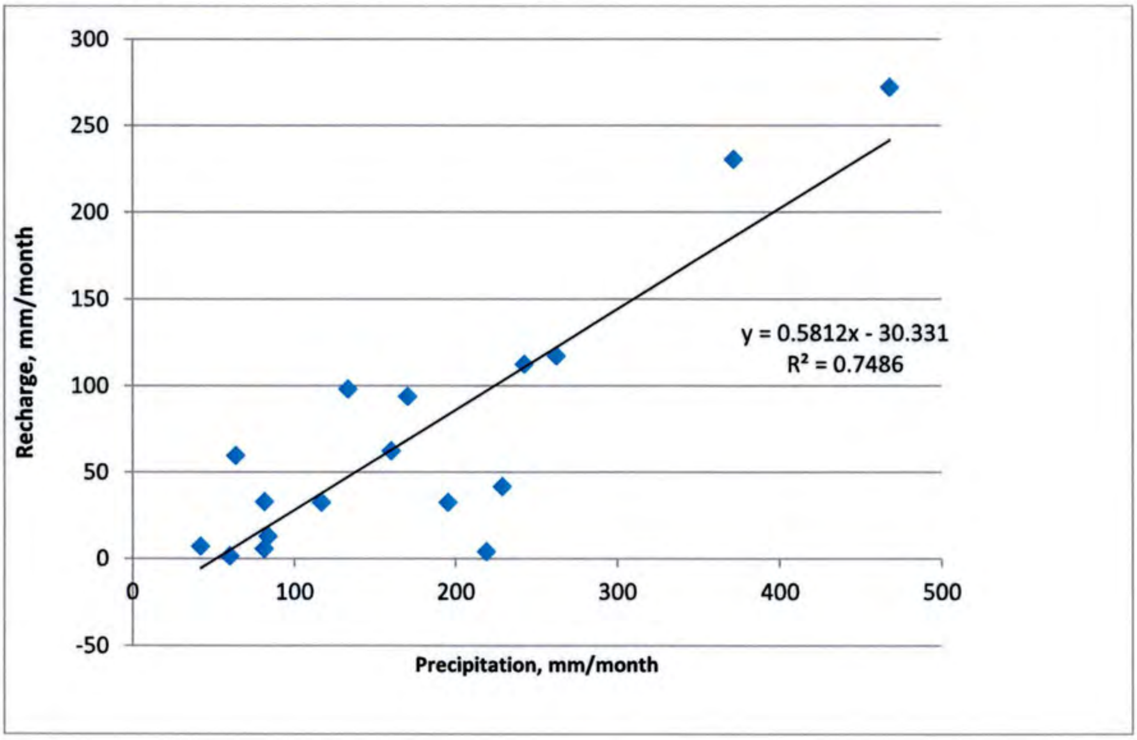
The average monthly data in Figure 11 shows a distinct seasonal pattern with the highest recharge during the winter months. Lowest recharge as a total and percentage occurs in October and November and then again from January to March. Recharge is consistent between sensors although in the months of highest recharge sensor 3 has a higher recording than the other two sensors.

Figure 11 Average Monthly Rainfall and Recharge



The overall relationship between monthly rainfall and monthly recharge is shown in Figure 12. The regression equation indicates that generally there is a threshold that has to be reached before recharge is initiated. The intercept is similar to that at the Kaharoa site suggesting 30mm might be the typical monthly threshold for recharge. This relationship is further considered in Section 3.0 where the data is combined to identify regionalisation opportunities.

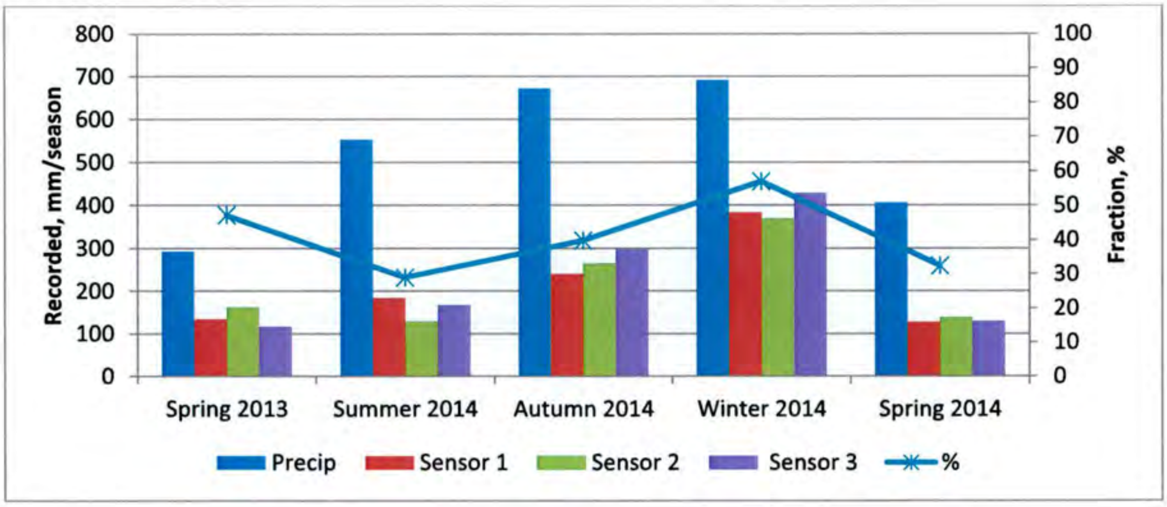
Figure 12 Relationship between monthly rainfall and recharge



2.2.3 Seasonal

Recharge averages 135mm in spring, 160mm in summer, 268mm in autumn and 394mm in winter. The seasonal pattern is shown in Figure 13. Recharge is over 50% of rainfall during winter and drops to less than 30% in the summer. It should be noted that this for only one year of record.

Figure 13 Seasonal Pattern



2.2.4 Annual

As there is less than 2 years of record no assessment of annual patterns has been undertaken.

2.3 Pongakawa at Pongakawa Bush Road

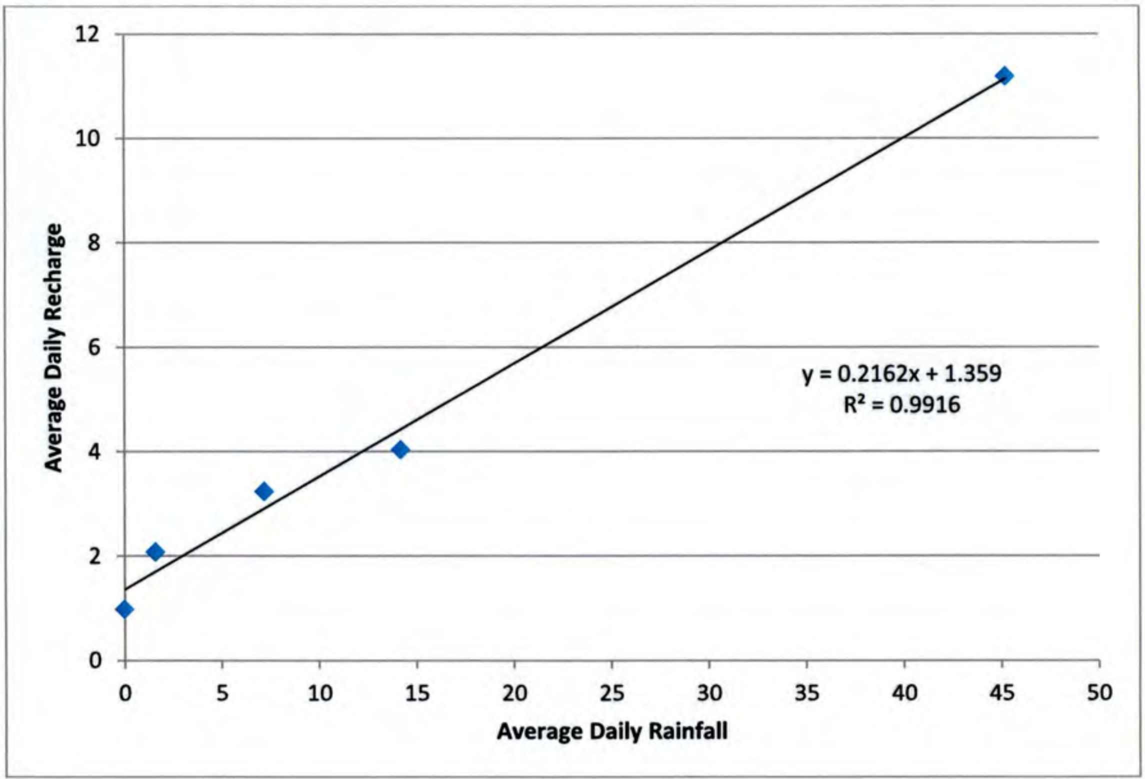
2.3.1 Daily

This site has over 4 years of records which allows an initial examination of the data for relationships between rainfall and recharge. A breakdown of daily data shows that even on days with little or no rain there is ongoing drainage through the soil profile. As daily rainfall increases there is a greater daily recharge. This suggests that both rainfall and hydraulic processes in the soil profile influence recharge. The data is summarised in Table 5 and the relationship in Figure 14.

Table 5 Daily Rainfall and Recharge

Minimum Rainfall (mm)	Maximum Rainfall (mm)	Average Rainfall (mm)	Average Recharge (mm)
0	0	0	1
0.01	5	2	2
5.01	10	7	3
10.01	20	14	4
20.01	163	45	11

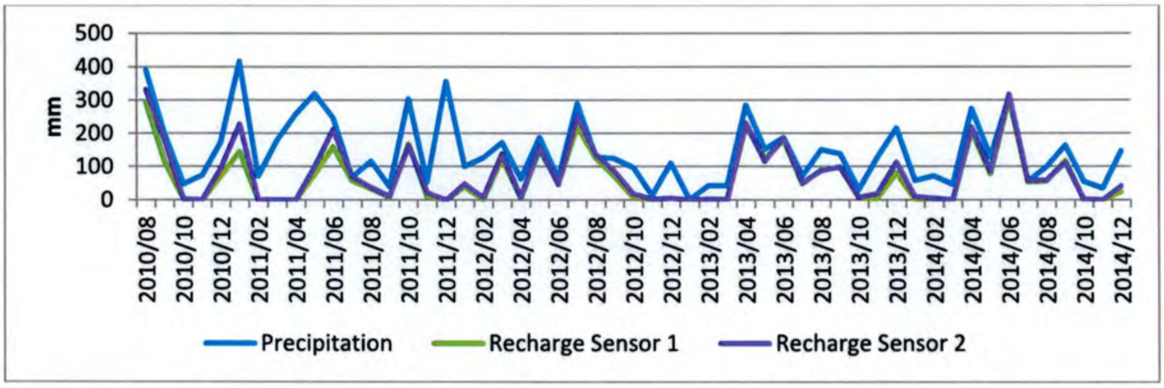
Figure 14 Daily Rainfall & Recharge



2.3.2 Monthly

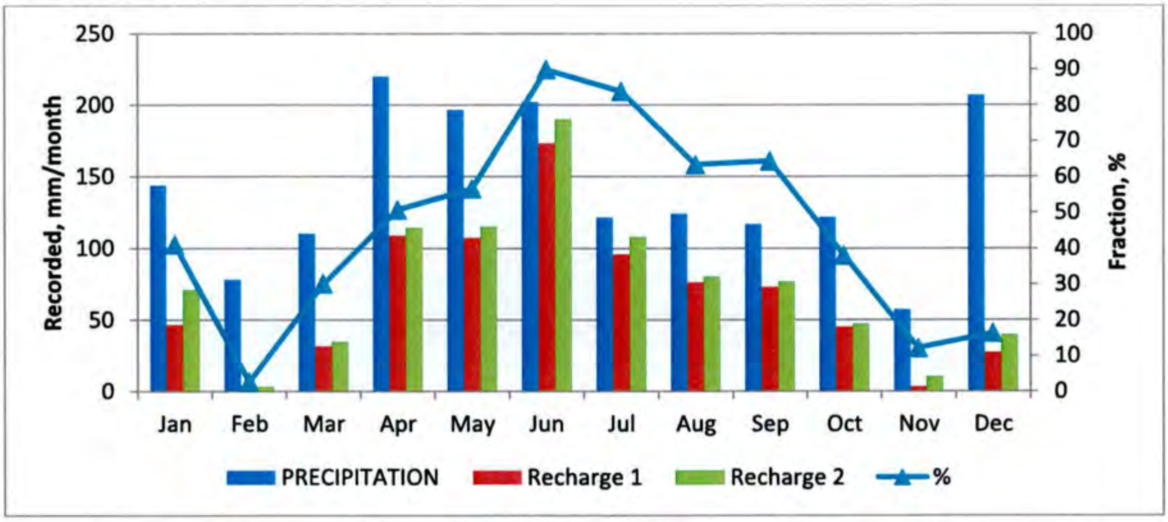
The monthly time series for rainfall and each lysimeter recharge is plotted in Figure 15. There is a similar pattern of recharge with each of the sensors even though sensor 2 averages over 100mm per year more than sensor 1.

Figure 15 Monthly Rainfall and Recharge Series



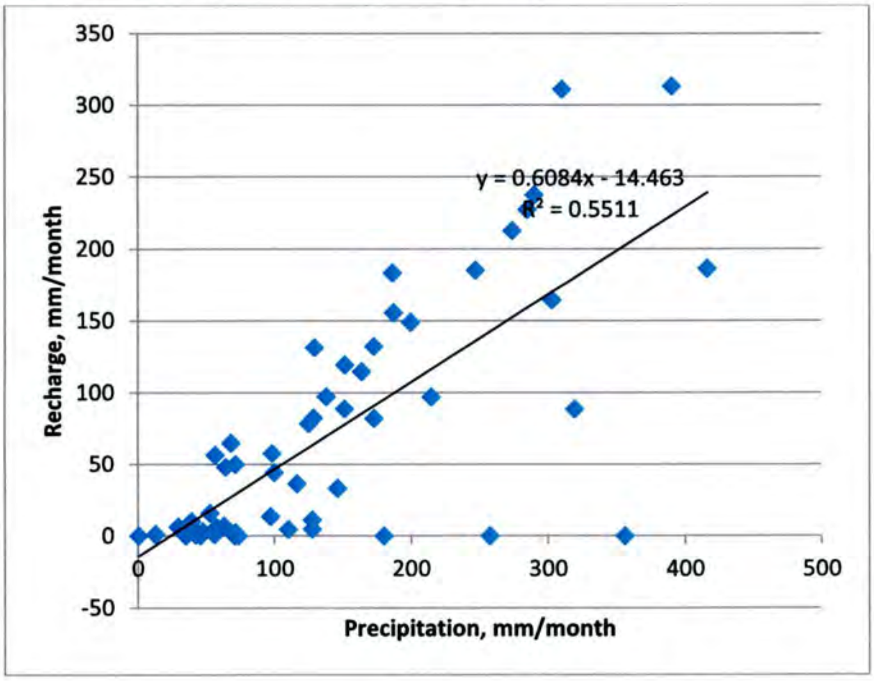
The average monthly data in Figure 16 shows a distinct seasonal pattern with the highest recharge during the winter months. Sensor 2 records more recharge in every month compared to sensor 1. The average proportion of rainfall that drains as recharge varies from less than 10% in February to over 80% in June and July.

Figure 16 Average Monthly Rainfall and Recharge



The overall relationship between monthly rainfall and monthly recharge is shown in Figure 17. There is a wide scatter of data points that shows a relatively low correlation, or explanation of the variance in recharge by only considering rainfall. BOPRC needs to confirm the data for this site because of this variance. For instance, there are months of between 200mm and 40mm of rainfall and no recharge while in other months both high rainfall and recharge occur. The annual evaporation cycle may be a factor in this but both the Mangorewa sites are reasonably close and have similar soil water holding capacity so there is no clear explanation at this stage for the variance.

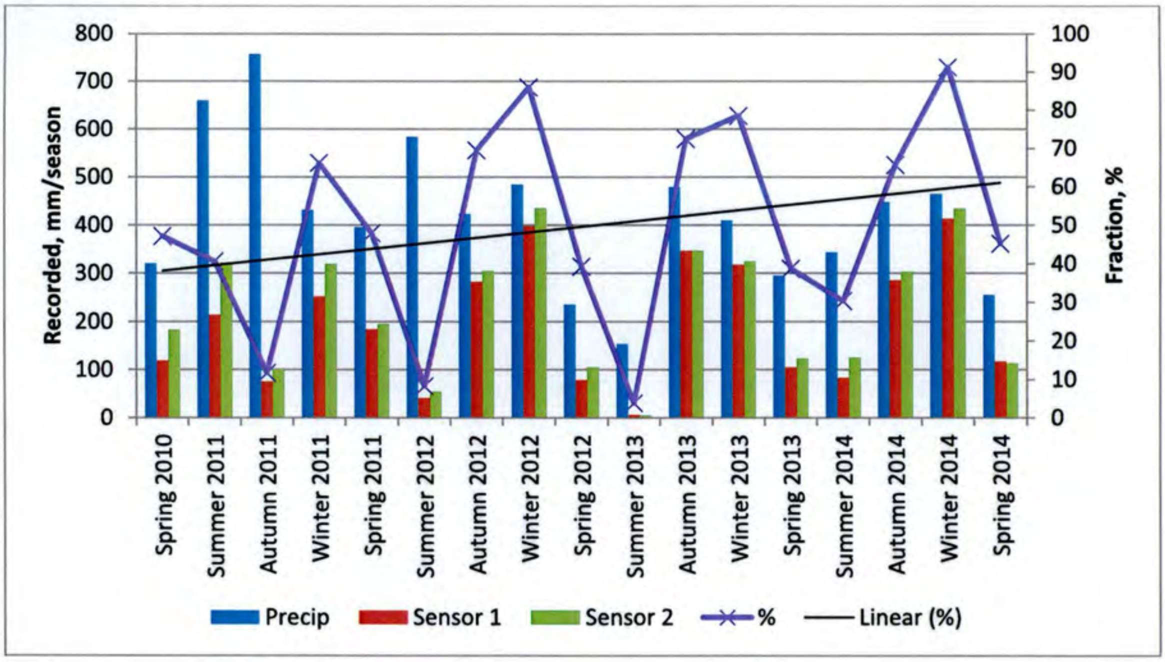
Figure 17 Relationship between monthly rainfall and recharge



2.3.3 Seasonal

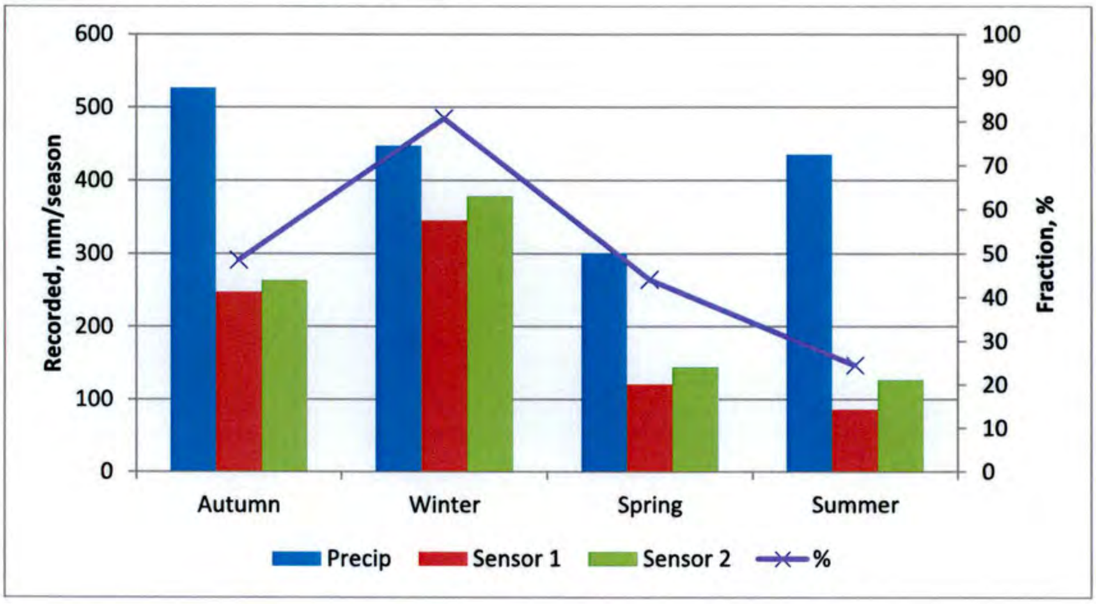
The seasonal pattern is shown for the 4 years of record in Figure 18. There is a strong annual cycle with recharge ranging from less than 10% of rainfall in the summer to greater than 60% in winter. There is also a consistent pattern showing sensor 2 as recording more than sensor 1. BOPRC needs to confirm if this is a sensor issue or a site effect.

Figure 18 Seasonal Pattern



Average seasonal distribution of rainfall and recharge is shown in Figure 19 with the highest recharge, with an average of 362mm, occurring in the winter months.

Figure 19 Average Seasonal Rainfall and Recharge



2.3.4 Annual

Annual recharge ranges from 42% to 58% of annual rainfall and averages 50% as shown in Table 6. Average recharge is 853mm per year.

Table 6 Annual rainfall and recharge

Year	Rainfall	Recharge	Recharge Percentage
2011	2247	832	42
2012	1727	851	51
2013	1339	789	48
2014	1514	940	58
Average	1707	853	50

2.4 Rangitaiki at Kokomoka

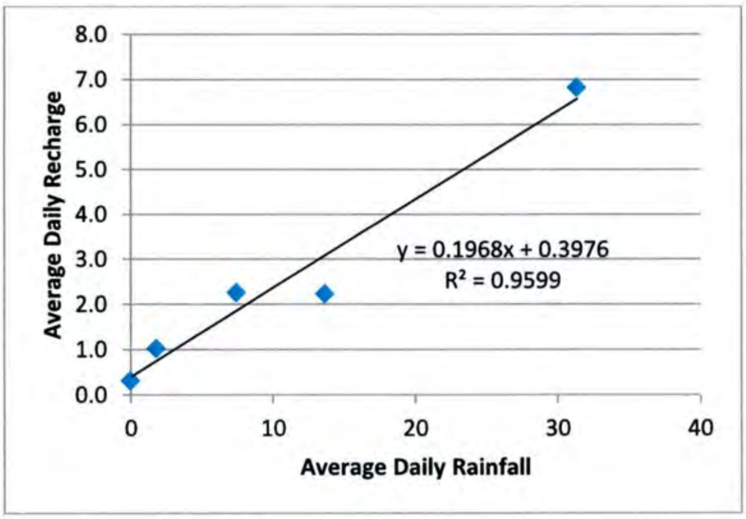
2.4.1 Daily

There is only 1 year of record at this site. A breakdown of daily data shows that even on days with little or no rain there is ongoing drainage through the soil profile. As daily rainfall increases there is an increase in the daily recharge. This suggests that both rainfall and hydraulic processes in the soil profile influence recharge. At this site the increase in average recharge with the increase in rainfall is less than at other sites. The data is summarised in Table 7 and the relationship in Figure 20.

Table 7 Daily Rainfall and Recharge

Minimum Rainfall (mm)	Maximum Rainfall (mm)	Average Rainfall (mm)	Average Recharge (mm)
0	0.3	0	0.3
0.4	5	1.8	1.0
5.01	10	7.4	2.3
10.01	20	13.65	2.2
20.01	48.1	31.35	6.8

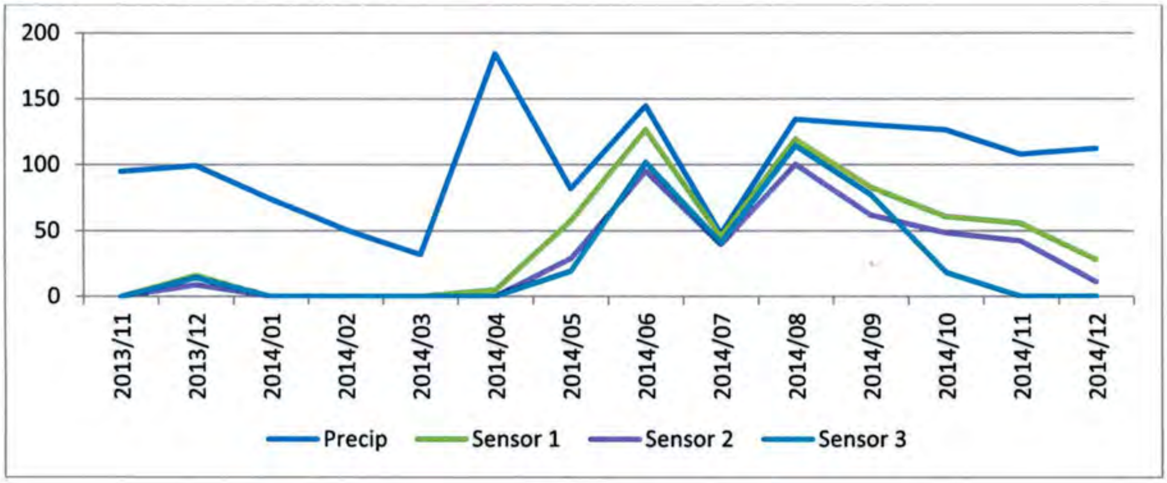
Figure 20 Daily Rainfall & Recharge



2.4.2 Monthly

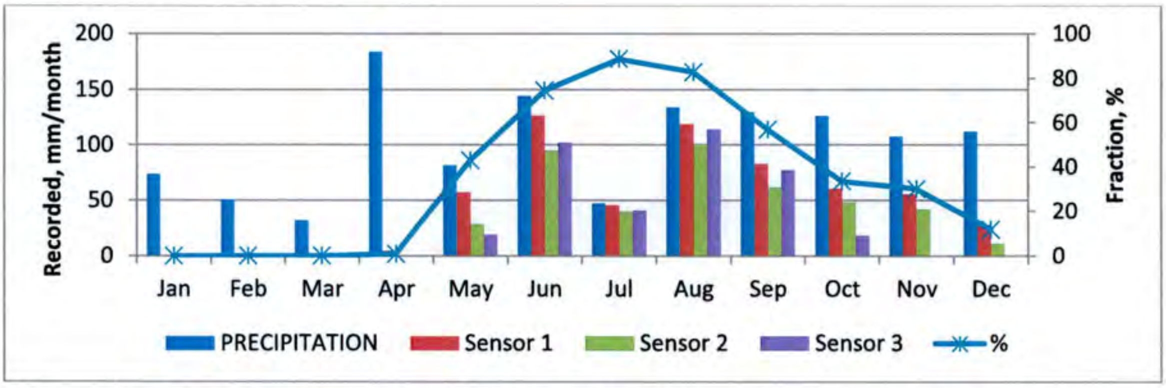
The monthly time series for rainfall and each lysimeter recharge is plotted in Figure 21. Over the summer of 2013 /14 there is very little recharge even though there is significant monthly rainfall totals. It is not until late in the autumn that the recharge volume increases

Figure 21 Monthly Rainfall and Recharge Series



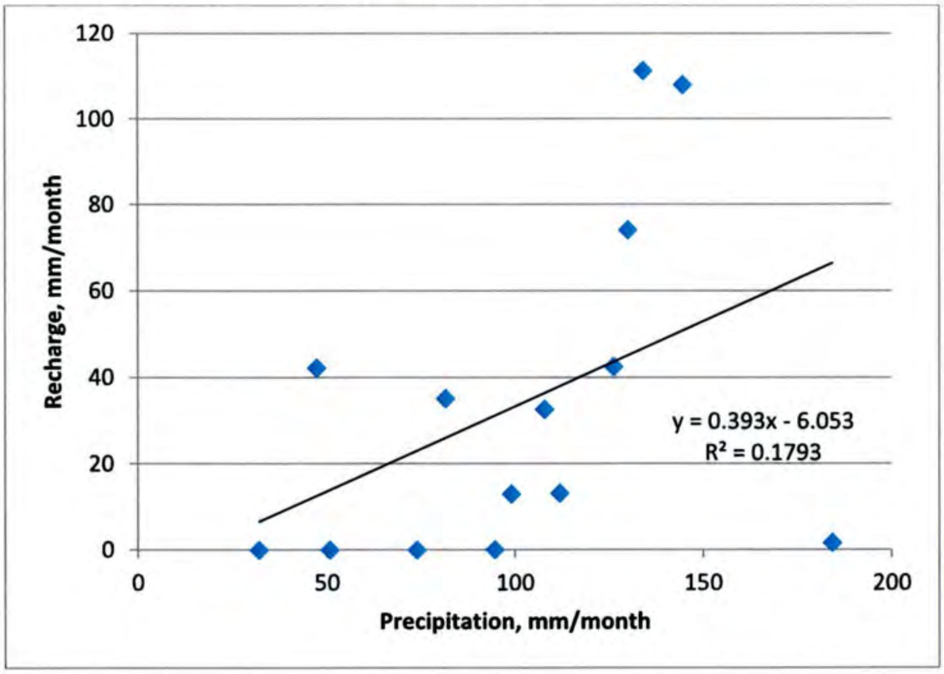
The average monthly data in Figure 22 shows a distinct seasonal pattern with the highest recharge during the winter months. Winter is also the time when the highest percentage of rainfall contributes to recharge when over 80% of the rainfall drains through the soil.

Figure 22 Average Monthly Rainfall and Recharge



The overall relationship between monthly rainfall and monthly recharge is shown in Figure 23 The plot shows a wide scatter of data and a very low explanation of the variance in the rainfall – recharge relationship. Clearly rainfall is not the sole dominating factor determining recharge occurrence and volume. The low summer recharge suggests that potential evaporation and soil water holding capacity may be other factors that influence recharge although the site does have a 200mm water holding capacity which is similar to the Mangorewa sites and the Pongakawa site. Further investigation is required to explain the physical process that is occurring at this site.

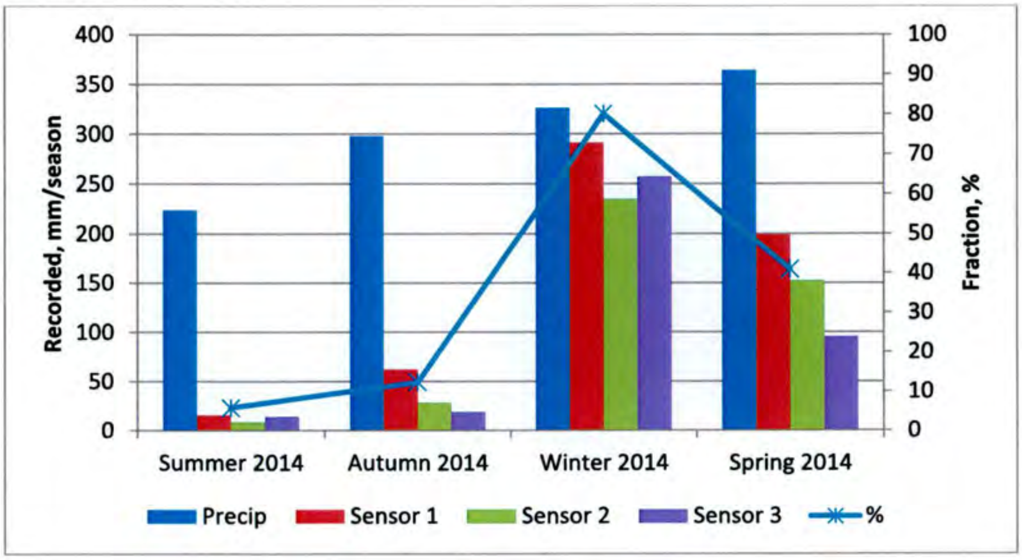
Figure 23 Relationship between monthly rainfall and recharge



2.4.3 Seasonal

The seasonal cycle is shown in Figure 24. The summer of 2014 had only 6% of the rainfall appearing as recharge while in the winter months recharge was 80% of the total rainfall.

Figure 24 Seasonal Pattern



2.4.4 Annual

Annual recharge has not been considered for assessment of trends as there is only one year of record where there was 460mm of recharge based on the average of the 3 sensors.

2.5 Wairoa at Lower Kaimai

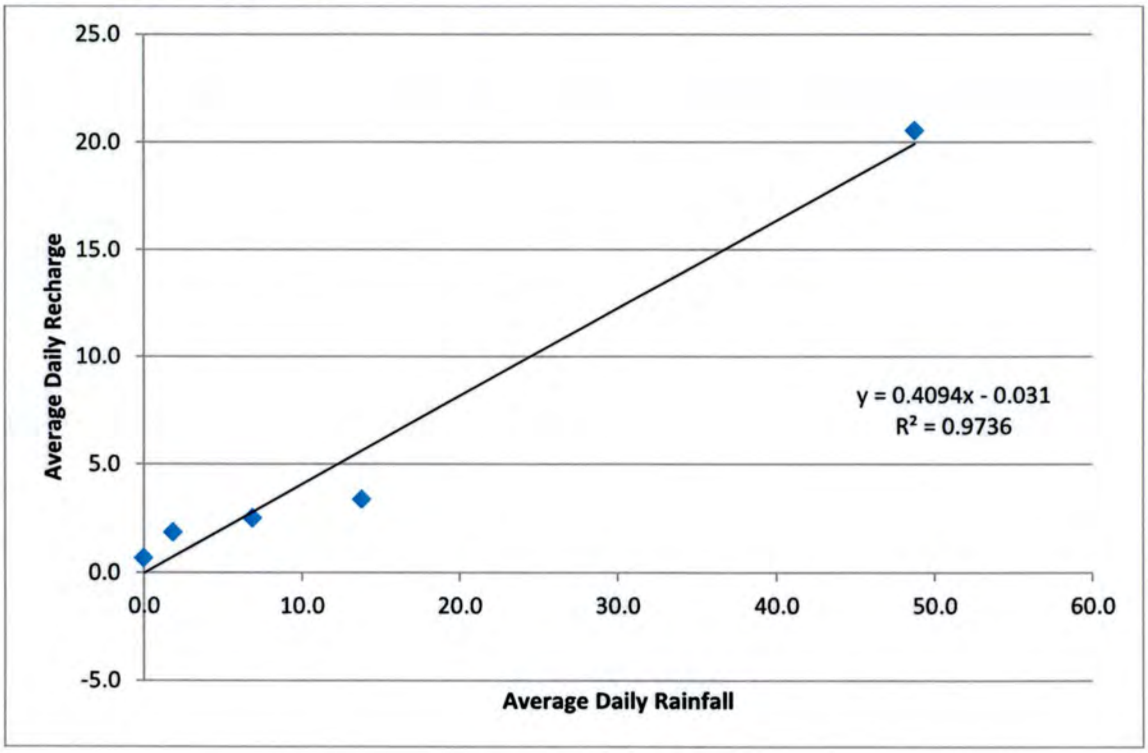
2.5.1 Daily

This site has only one year of record. A breakdown of daily data shows that even on days with little or no rain there is ongoing drainage through the soil profile. As daily rainfall increases there is an increase in the daily recharge. This suggests that both rainfall and hydraulic processes in the soil profile influence recharge. The data is summarised in Table 8 and the relationship in Figure 25.

Table 8 Daily Rainfall and Recharge

Minimum Rainfall (mm)	Maximum Rainfall (mm)	Average Rainfall (mm)	Average Recharge (mm)
0	0	0	0.7
0.09	5	1.8	1.9
5.01	10	6.9	2.5
10.01	20	13.8	3.4
20.01	158.6	48.7	20.5

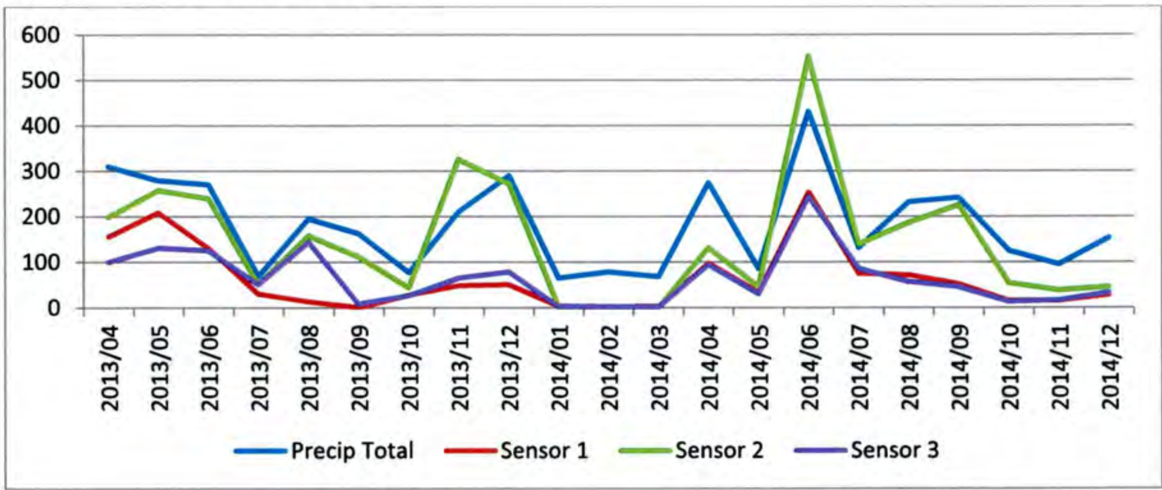
Figure 25 Daily Rainfall & Recharge



2.5.2 Monthly

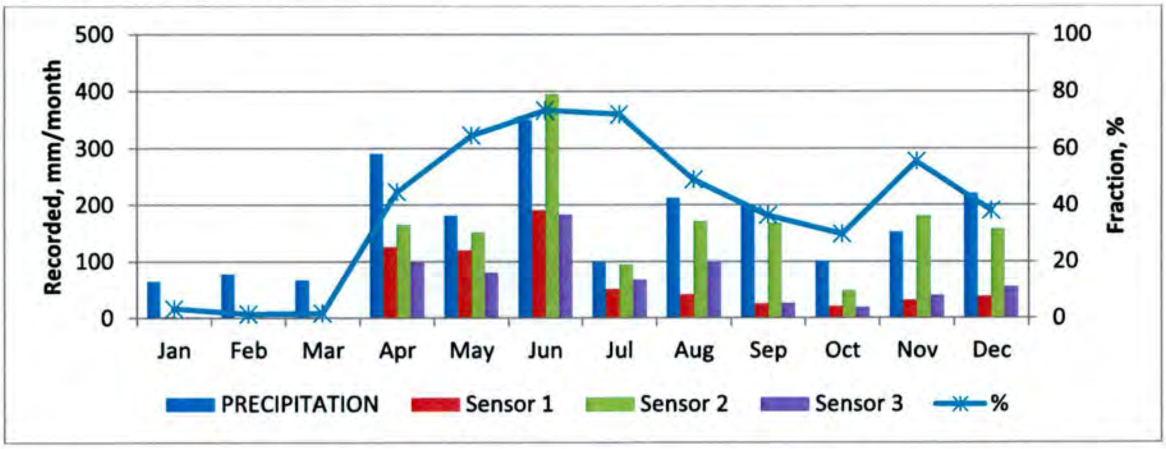
The monthly time series for rainfall and each lysimeter recharge is plotted in Figure 26. There is a similar pattern of rainfall and recharge from all of the sensors but it is noticeable that sensor 2 has a significantly higher recharge total than the other two sensors. This situation requires further investigation to understand why these totals from sensor 2 are so much higher than to those at the other sensors.

Figure 26 Monthly Rainfall and Recharge Series



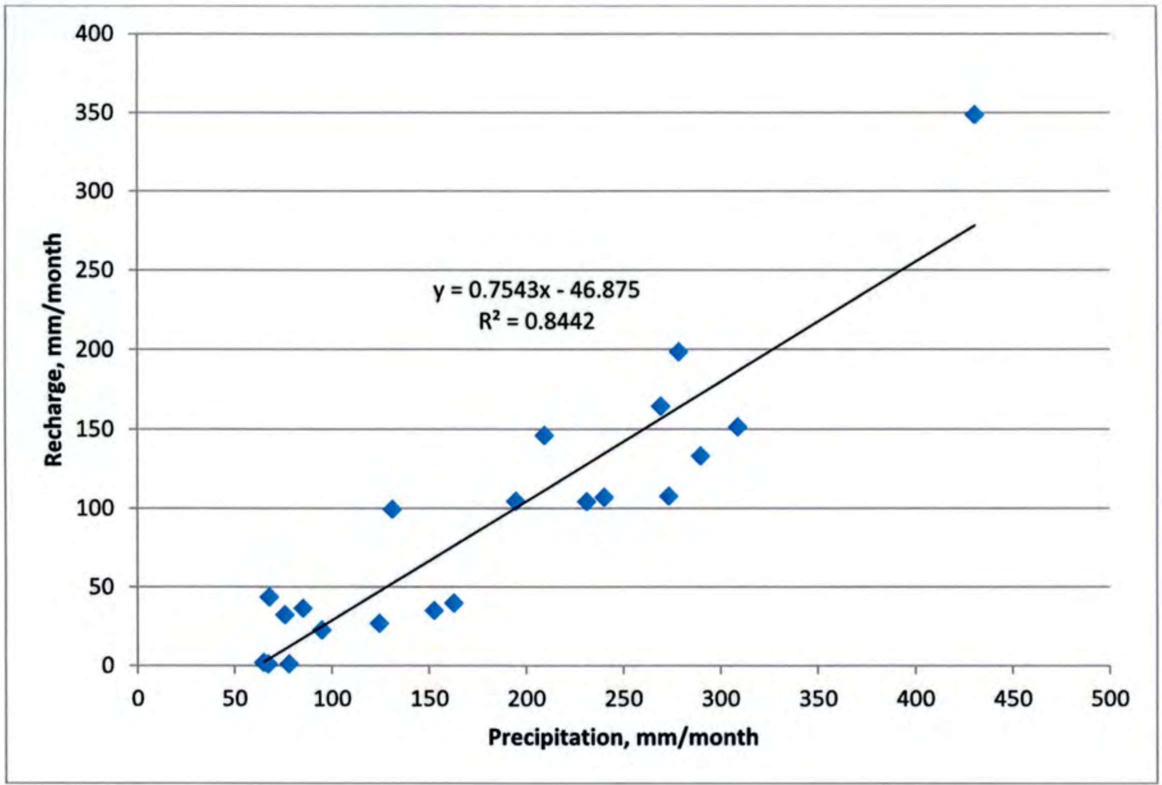
The average monthly data in Figure 27 shows a strong seasonal difference between January and March when there is negligible recharge and subsequent autumn and winter months when recharge is over 60% of rainfall. It is noticeable how much more recharge is measured at sensor 2 in the plot. In June the total recharge is higher than the rainfall total. These observations on sensor 2 raise questions as to the validity of the data from this sensor.

Figure 27 Average Monthly Rainfall and Recharge



The overall relationship between monthly rainfall and monthly recharge is shown in Figure 28. The plot indicates that rainfall totals largely explain the variance in the data. It also indicates that there is a relatively high threshold, 46mm, in terms of rainfall total before recharge is initiated on a monthly basis.

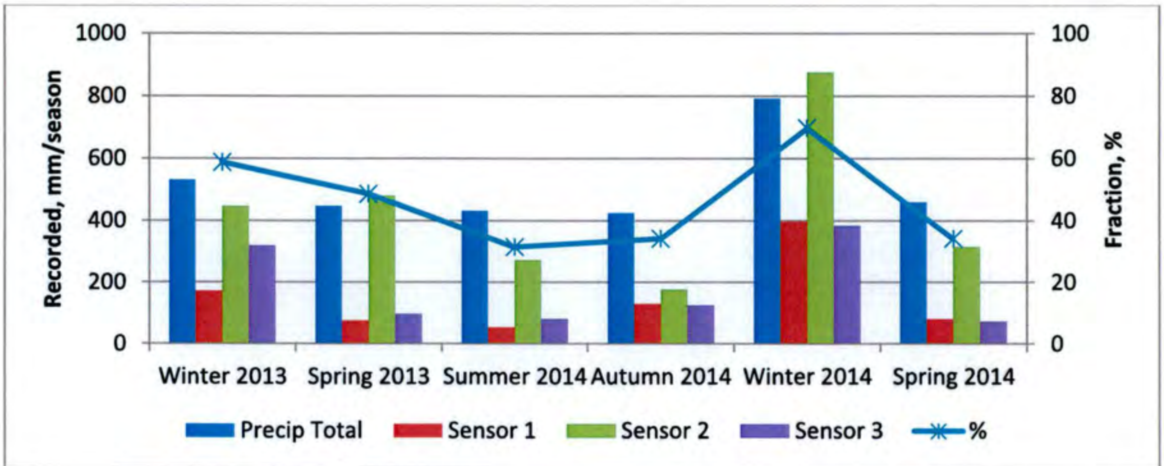
Figure 28 Relationship between monthly rainfall and recharge



2.5.3 Seasonal

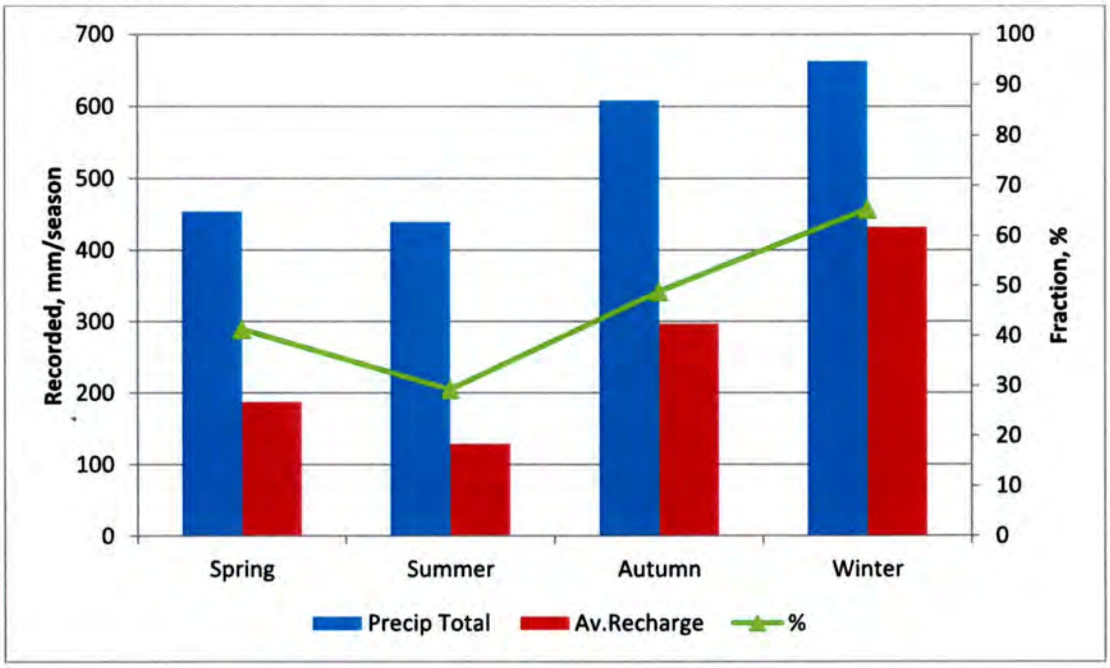
The seasonal pattern is shown in Figure 29. The results are likely to be significantly skewed because of the relatively high recharge recorded at sensor 2. This sensor needs to have its data reviewed before conclusions can be drawn with confidence.

Figure 29 Seasonal Pattern



Average seasonal distribution of rainfall and recharge is shown in Figure 30 with the highest recharge occurring in the winter months.

Figure 30 Average Seasonal Rainfall and Recharge



2.5.4 Annual

Annual recharge has not been assessed in detail as there is only 18 months of record from this site so trend assessment is not appropriate.

2.6 Site Recharge

Annual recharge comparisons between sites are impossible because of the varying lengths of record. However, it is interesting to note that Rangitaiki recorded 460mm of recharge while the other four sites ranged from 853mm to 1112mm. The Kaimai site had totals between 720mm and 740mm for sensors 1 and 3 but sensor 2 had more than twice that at 1676mm.

The Rangitaiki and Wairoa sites both had relatively low summer recharge compared to the other three sites. This may have been simply due to the short record and the climate in that year. However, simply running an investigation solely considering rainfall and recharge with a single point soil moisture measurement is likely to end with some of the variance in the rainfall recharge relationship unexplained. Site soil physical and hydraulic properties need to be considered along with evaporative losses at the sites. All parameters in the water balance need to be measured and the attenuation properties of the soil on recharge drainage need to be understood.

3.0 Regionalisation

3.1 Introduction

Upscaling or regionalisation of recharge data from the lysimeters to catchment level is desirable to provide inputs to regional groundwater balances. Recharge is primarily a function of rainfall inputs, evaporative or drainage losses through the soil profile and the water storage volume of a given soil profile. At the lysimeter sites rainfall and drainage is measured, soil moisture is monitored but at only one point in the soil profile and evaporative losses are not recorded.

To assess regionalisation possibilities the full range of measured parameters is really required and for a considerable number of years of record. In this situation some of the parameters of the water balance are not measured.

Despite these limitations the data has been analysed a number of ways to provide an insight into the potential for regionalisation and assess future direction of the monitoring. The outcome of this type of approach is never a definitive answer but it should provide a direction for the future.

3.2 Rainfall – Recharge

Monthly recharge has been assessed by developing a simple linear regression model using site rainfall and potential evapotranspiration (PET) records from a synthetic site such that the annual cycle is represented. A simple balance of rainfall minus PET has been regressed against measured recharge. Rainfall has also been regressed against recharge. A comparison of regression analyses shows a small increase in explanation of the variance, with a higher correlation, by the inclusion of PET in the analysis. The statistical significance of the second variable has not been tested but it does suggest that further consideration needs to be given to the inclusion of PET in future observations and analysis when there is a larger database.

3.3 Soil Moisture Threshold

All the preceding analysis indicates that the trend line intercept on a rainfall – recharge relationship model is not zero and that there is a rainfall input threshold before significant recharge occurs. The simple water balance approach has been applied to site monthly data, including the soil moisture record where it has been assumed that the point record represents the complete soil column. A 3 parameter model has been developed to compare computed with observed recharge. The model parameters include the proportion of rainfall that runs off and the rainfall threshold before recharge occurs. Results worth consideration have only been achieved at the two sites. Consequently the assessment to consider regionalisation potential is limited but from the results it can be inferred that plant available soil moisture and potential evapotranspiration are variables that influence recharge.

The optimised results show (Table 9) that once the recharge threshold has been reached over 80% of the rainfall contributes to recharge. The optimised results show;

- The moisture threshold is higher for the soil with the greater water holding capacity,
- Average monthly evapotranspiration is in the range of 80mm to 90mm, and
- Average monthly recharge is more than 80% of rainfall once the soil moisture threshold is exceeded.

Table 9 Soil Moisture Threshold

Site	Plant Available Soil Moisture (mm)	Proportion of Rainfall as Recharge above Threshold	PET (mm/month)	Threshold (mm)
Mangorewa at Kaharoa	200	0.82	79	51
Wairoa at Lower Kaimai	120	0.85	91	37

3.4 Site variability

The preceding analysis indicated that for some months and at some sites there is a significant difference in recharge measured in lysimeters. The differences in recharge between sites has been standardised to facilitate comparison. This has been assessed by consideration of the months where there are concurrent records from all sites and lysimeters. The period considered is from November 2013 through to December 2014; a total of 14 months or data points. The approach has been to compare each lysimeter with all the others using a **standardised difference methodology;** $\sqrt{((X_i-Y_i)^2)/n}$.

The results are shown in Table 10. The results show that some sites have strong similarities while others are exceptions. These exceptions show differences between sites but where these occur between lysimeters at the same site then the relevance for regionalisation is in doubt. For instance, the Rangitaiki site has relatively strong differences to other sites but much less difference between the lysimeter sensors at the Rangitaiki site, suggesting it is representative of its area and that location differs from elsewhere in terms of recharge. A similar pattern occurs at the Kaimai site except for senor 2 which has significant differences with every other sensor including sensors 1 and 3 at the same site. In this case there is as difference at the one site between lysimeters as there is to other sites. This makes the site very difficult to be of relevance for regionalisation. For the Mangorewa sites and Pongakawa the differences are similar for between site and between sensors other than at Pongakawa where there is very little difference between sensors. In these instances it may be that only one of the sites is required to represent an area. The results suggest that it may be possible to achieve regionalisation of a recharge model but much more data, both over time and on the physical parameters at the site, are required to establish an extensive analysis of the variance.

Table 10 Sensor Relationships

	Mangorewa at Kaharoa 1	Mangorewa at Kaharoa 2	Mangorewa at Waite B 1	Mangorewa at Waite B 2	Mangorewa at Waite B 3	Pongakawa 1	Pongakawa 2	Rangitaiki at Kokomoka 1	Rangitaiki at Kokomoka 2	Rangitaiki at Kokomoka 3	Wairoa at Lower Kaimai 1	Wairoa at Lower Kaimai 2	Wairoa at Lower Kaimai 3
Mangorewa at Kaharoa 1	0	32	22	21	33	33	35	76	80	77	47	140	47
Mangorewa at Kaharoa 2		0	42	37	53	41	49	57	62	57	39	148	44
Mangorewa at Waite B 1			0	20	23	28	27	82	87	84	46	134	46
Mangorewa at Waite B 2				0	21	26	28	80	84	82	44	142	46
Mangorewa at Waite B 3					0	28	22	96	101	99	55	130	55
Pongakawa 1						0	12	83	89	87	44	138	47
Pongakawa 2							0	89	96	94	49	131	50
Rangitaiki at Kokomoka 1								0	16	25	53	176	56
Rangitaiki at Kokomoka 2									0	16	57	185	60
Rangitaiki at Kokomoka 3										0	56	182	59
Wairoa at Lower Kaimai 1											0	143	11
Wairoa at Lower Kaimai 2												0	140
Wairoa at Lower Kaimai 3													0

4.0 Conclusions & Recommendations

4.1 Scope

This assessment has been undertaken based on the data supplied by BOPRC. It has focussed on;

- Analysis of the recharge component,
- Consideration of methodologies for the recharge analysis,
- Consideration of the relationship between recharge and climate variations/trends,
- Consideration of upscaling or regionalisation of results to a catchment level, and
- Evaluation of the existing and proposed lysimeter network

The assessment has;

- Quantified the recharge at 5 sites by considering daily, monthly, seasonal and annual recharge. In some instances the length of record which is only 1 year, has limited the extent of the assessment and particularly any consideration of trends.
- Considered methodologies that have included consideration of actual records and consolidation of the 15 minute data; review of simple regression models of daily and monthly data; trend analysis of seasonal and annual data where sufficient record exists; and development of a more complex 3 parameter model to estimate recharge.
- Considered regionalisation opportunities through the use of a 3 parameter model that could be used for estimation of recharge, and the standardised differences in data between lysimeters and sites to assess the magnitude of variance within and between sites.
- The evaluation of the existing network is limited to the outcomes of the assessment results rather than having a specific focus. The limited data record and the lack of information on some soil and evaporation parameters at most of the sites mean that detailed consideration of the network is not feasible.

4.2 Results

The results have highlighted a number of features;

- Recharge continues on days that there is no rainfall.
- The proportion of daily rainfall that contributes to recharge varies with rainfall depth but there may be other factors involved such as the season and soil physical and hydraulic properties.
- There is a marked seasonal difference in the proportion of rainfall that contributes to recharge and the total recharge volume.
- There is a variation in annual recharge between sites.
- Trend analysis at Kaharoa and Pongakawa indicate that there is an overall increase in the recharge volume.
- A model that predicts recharge based on an initial rain threshold and a proportional relationship factor for the percentage of rainfall that recharges is a strong possibility when more data becomes available.
- Evaporation and soil property data are required to improve the explanation of the variance in the relationship between rainfall and recharge.
- There are "outliers" in the rainfall – recharge relationships that need investigation. This applies to both rainfall and no recharge and recharge that exceed rainfall on a monthly basis.
- There are significant differences between recharge recorded at lysimeters at the same site. These are not outliers but are consistent over a period of time and need to be investigated.

4.3 Recommendations

The results of this assessment indicate a number of actions are required, including;

- Explanation (and possible corrective action) of outliers is required.
- Explanation of differences in recharge totals between lysimeters needs to be understood and corrective actions developed and implemented as required.

- Soil physical and hydraulic properties at all sites need to be determined.
- Evaporation should be recorded at each site to allow the development of regionalisation and recharge prediction models. Historical estimates should be obtained through the NIWA virtual climate station database. This could continue to be the source of evaporation data or on site direct measurement or indirect estimation of evaporation needs to be undertaken
- The initial attempts to understand regional patterns needs to be developed further using a GIS environment. Further focus needs to be on understanding the parameters that influence recharge so that they can be mapped and significant differences identified in the spatial domain. Until this is possible resolution of an optimal network is not possible.
- From the Mangorewa site with 9 years of record it would appear that at least 10 years of record from every site will be required to establish recharge trends. Shorter records of 4 years appear to provide valuable insight into recharge. Consequently a long term investment needs to be made in the monitoring of these sites and frequent standardised assessment on an annual cycle should be undertaken for data review and updating of the recharge estimates.
- More detailed statistical analysis of difference between and within sites needs to be undertaken to understand recharge variability. This could then be combined with a GIS based approach to regionalisation.

5.0 Standard Limitation

AECOM Consulting Services (NZ) Limited (AECOM) has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of Bay Of Plenty Regional Council and only those third parties who have been authorised in writing by AECOM to rely on this Report.

It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this Report.

It is prepared in accordance with the scope of work and for the purpose outlined in the contract dated 10th June 2015.

Where this Report indicates that information has been provided to AECOM by third parties, AECOM has made no independent verification of this information except as expressly stated in the Report. AECOM assumes no liability for any inaccuracies in or omissions to that information.

This Report was prepared between 10th June 2015 and 4th August 2015 and is based on the data provided by BOPRC at the time of preparation. AECOM disclaims responsibility for any changes that may have occurred after this time.

This Report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This Report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

Except as required by law, no third party may use or rely on this Report unless otherwise agreed by AECOM in writing. Where such agreement is provided, AECOM will provide a letter of reliance to the agreed third party in the form required by AECOM.

To the extent permitted by law, AECOM expressly disclaims and excludes liability for any loss, damage, cost or expenses suffered by any third party relating to or resulting from the use of, or reliance on, any information contained in this Report. AECOM does not admit that any action, liability or claim may exist or be available to any third party.

Except as specifically stated in this section, AECOM does not authorise the use of this Report by any third party.

It is the responsibility of third parties to independently make inquiries or seek advice in relation to their particular requirements and proposed use of the site.

Any estimates of potential costs which have been provided are presented as estimates only as at the date of the Report. Any cost estimates that have been provided may therefore vary from actual costs at the time of expenditure.