Water Quality Index applied to the Exploits River Watershed

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1.1 DESCRIPTION OF THE INDEX

The water quality indices are calculated for the following three different uses:

(a) **Drinking Water Quality Index:** drinking, recreation, irrigation, and livestock watering uses.

(b) **Aquatic Water Quality Index:** aquatic life and wildlife protection uses.

(c) **Overall Water Quality Index:** all uses including the protection of human health, aquatic ecosystems, wildlife etc.

The environmental standards used to compare the attainment of water quality objectives for each of the above cases are listed in Table 1. As shown in the table, the most stringent regulations are used for determining overall water quality indices followed by aquatic and then drinking water uses.

The determination of the water quality index is based on the following three major factors:

1. The number of objectives that are not met.
2. The frequency with which the objectives are not met.
3. The magnitude by which the objectives are not met.

Water Uses		Overall	Drinking	Aquatic
Iron (Fe)	(mg/l)	0.3	0.3	0.3
Manganese (Mn)	(mg/l)	0.05	0.05	0.1[BC]
Lead(Pb)	(mg/l)	0.001	0.01	0.001
Nickel (Ni)	(mg/l)	0.025	0.2[BC]	0.025
Zinc (Zn)	(mg/l)	0.03	5	0.03
Aluminum (Al)	(mg/l)	0.005	0.2[BC]	0.005
Chromium (Cr)	(mg/l)	0.002	0.05	0.002
Copper (Cu)	(mg/l)	0.002	1	0.002
Specific Conductance (Cond.)	(uS/cm)	700[BC]	700[BC]	N/A
Turbidity	(JTU)	1	1	N/A
Dissolved Oxygen (DO)	(mg/l) (Minimum)	5[BC]	N/A	5[BC]
pH	Maximum	8.5	8.5	9
	Minimum	6.5	6.5	6.5
Phosphorous (P)	(mg/l)	0.1*	0.1*	0.1*
Dissolved Organic Carbon (DOC)	(mg/l)	5[ON]	5[ON]	N/A
Arsenic (As)	(mg/l)	0.025	0.025	0.05
Cadmium (Cd)	(mg/l)	0.0002	0.005	0.0002
Mercury (Hg)	(mg/l)	0.0001	0.001	0.0001

N/A = Not Applicable

[BC] British Columbia Provincial Water Quality Guidelines

[ON] Ontario Provincial Water Quality Guidelines

* Recommended as the Maximum Desirable Concentration

All other criteria are from *Canadian Environmental Quality Guidelines* and *Guidelines for Canadian Drinking Water Quality*

Table 1. Water Quality Standards for Different Water Uses

These three factors are combined to form the index. These index values may fall into one of the following five rankings:

Excellent: This ranking is used when the state of water quality for a specific use is close to natural or pristine level and there is no threat or impairment to that use.

Good: Water quality is classified as "good" if there is a minor degree of threat or impairment and conditions rarely depart from the natural or desirable levels.

Fair: When the quality is such that most uses are protected but a few uses are threatened or impaired. In this case, a single use may be temporarily interrupted and conditions sometime depart from natural or desirable levels.

Borderline: In this case, the conditions often depart from natural or desirable levels. Several uses are threatened or impaired and more than one use may be temporarily interrupted.

Poor: When conditions usually depart from natural or desirable levels and most uses are threatened or impaired and also several uses may be temporarily interrupted, it is classified as "poor" quality.

Quantitative definition of these rankings is provided in Table 2. In general, the lower the environmental indicators the better is the quality of water for a specific use. In this project, the WQI are calculated using the British Columbia (BC) Approach.

1.1.1 BC Approach

In the BC approach, WQI values are calculated for overall water, aquatic, and drinking uses using the following formulation:

$$Index = \sqrt{F_1^2 + F_2^2 + (F_3 / 3)^2}$$

Index rank = *Index/1.45*

Where,

F_1 = number of objectives not met as a percentage of the number of objectives checked. For a period of one year, F_1 is calculated by summing the number of objectives not met in that year, dividing by the total number of objectives measured that year, and multiplying by 100. For a given type of water quality index determination, if n is the number of objectives (variables) which do not meet a water quality standard in a specified period and if N is the total number of objectives measured in that period then,

$$F_1 = (n/N)*100$$

F_2 = frequency with which the objectives are not met. It is measured as a percentage of the number of times objectives are not met in a given time period, of all instances the objectives are checked during that period. For a given type of water quality index determination, if m is the number of times the objectives do not meet the water quality standard for the use and if M is the number of times the objectives (variables) are measured, then

$$F_2 = (m/M)*100$$

F_3 = a measure of the maximum amount by which the objectives are not being met in a given time period. For the common case of the objective expressed as a maximum, this deviation is calculated by

subtracting the objective value from the maximum measurement exceeding the objective, dividing by this maximum measurement, and multiplying by 100. This factor is calculated as follows:

$$F_3 = \text{Max}\,[\{(XMM_{i,j} - Std_j)/XMM_{i,j})*100\}] \text{ for all } i,j$$

Where,

$XMM_{i,j}$ is the maximum or minimum value of the jth variable (objective) in the ith sample. For all variables except for DO and pH, maximum values are used.

Std_j is the permissible limit of jth variable for the specific water quality index determination.

	F_1	F_2	F_3	Index Value	Index Rank
Excellent	0 - 2	0 - 1	0 - 9	0 - 4	0 -3
Good	3 - 14	2 - 14	10 - 45	5 - 25	4 - 17
Fair	15 - 35	15 - 40	46 - 96	26 - 62	18 - 43
Borderline	36 - 50	41 - 60	97 - 99	63 - 85	44 - 59
Poor	51 - 100	61 - 100	99.1 - 100	86 - 145	60 - 100

Table 2. The Index Values Used in the BC Approach

1.2 WATER QUALITY INDICES AT SAMPLING STATIONS

23 stations were used in the WQI analysis (Figure 1). The WQI were evaluated for overall use, drinking water use, and aquatic water use.

Figures 2, 3, and 4 summarize the water quality indices for overall use, drinking water use, and aquatic water use respectively. The overall water index ranged from borderline to fair at all the stations except for Corduroy Brook where it was poor. No site was good or excellent.

The drinking water index similarly ranged from borderline to fair at all the stations except for four sites (Lloyd's River, Exploits River @ Millertown, Badger Brook, and Exploits River @ Bond Bridge) where it was good.

Following the pattern of the overall water index, the aquatic water index ranged from borderline to fair at all the stations except for Corduroy Brook where it was poor.

1.3 WATER QUALITY TRENDS

To analyze the WQI trend over time, data that spanned over a few years was needed. However since the data length for the 23 stations was not of long enough duration, data from five long-term stations was used for the purpose. Water quality data for these stations was available from 1987 to 1994.

Figure 1. Exploits River Basin: Water Quality Stations

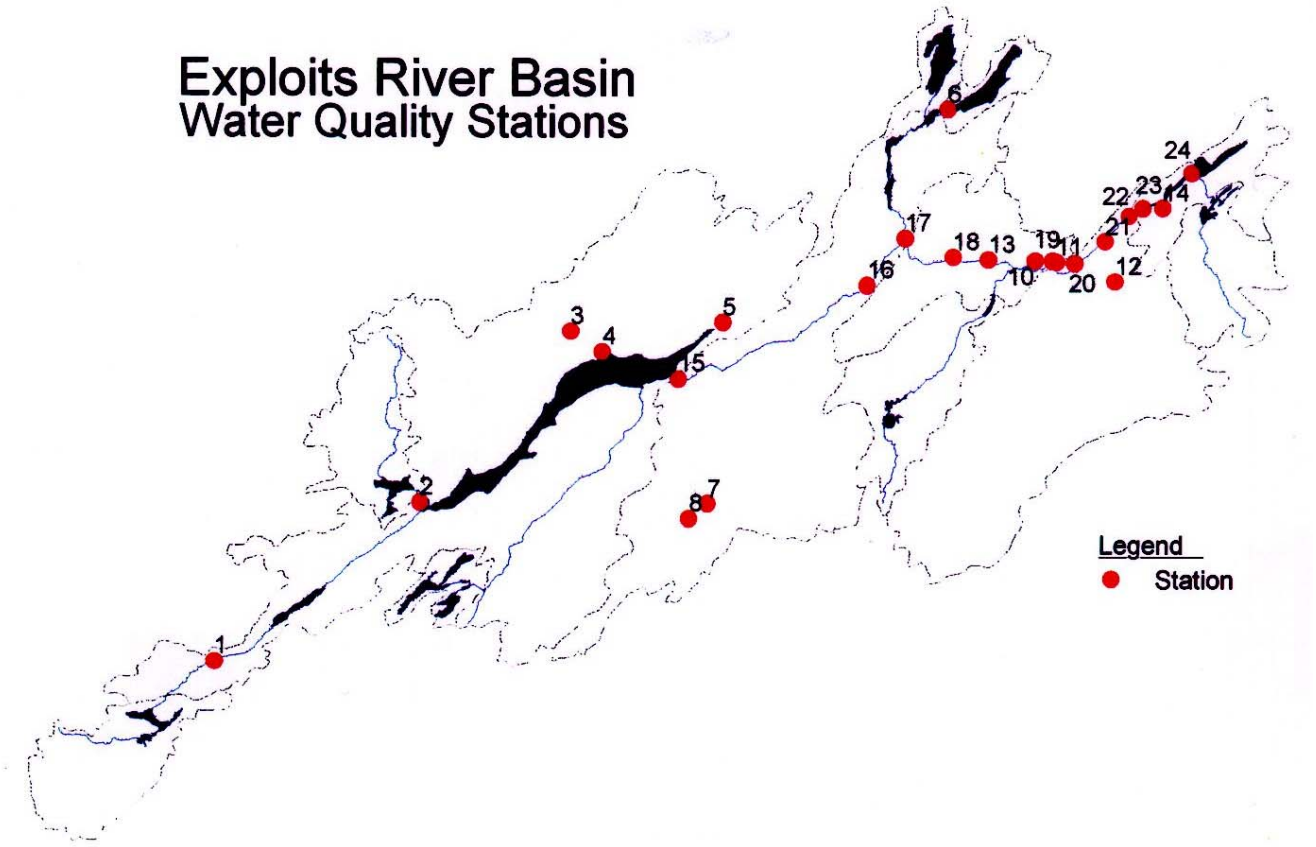


Figure 2. Exploits River Basin: Overall Water Quality Index

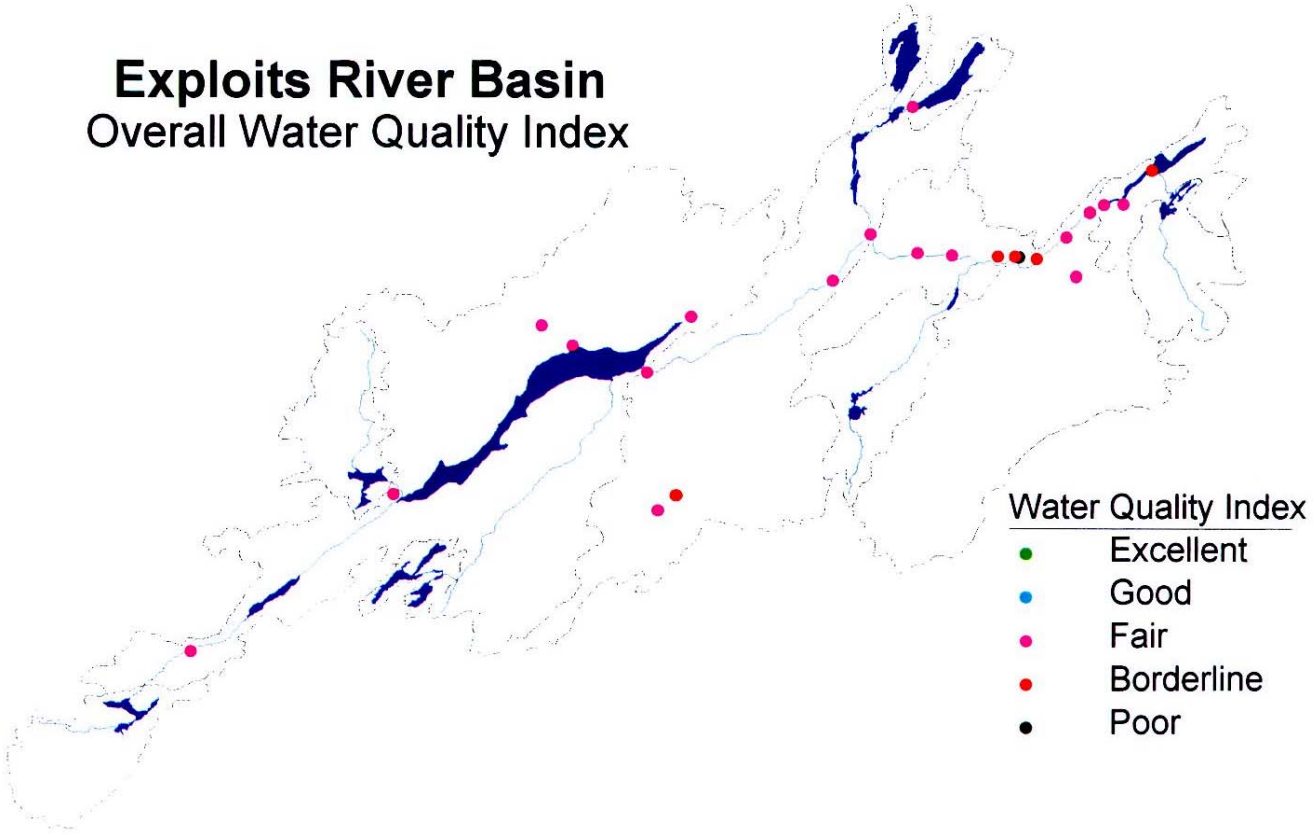


Figure 3. Exploits River Basin: Drinking Water Quality Index

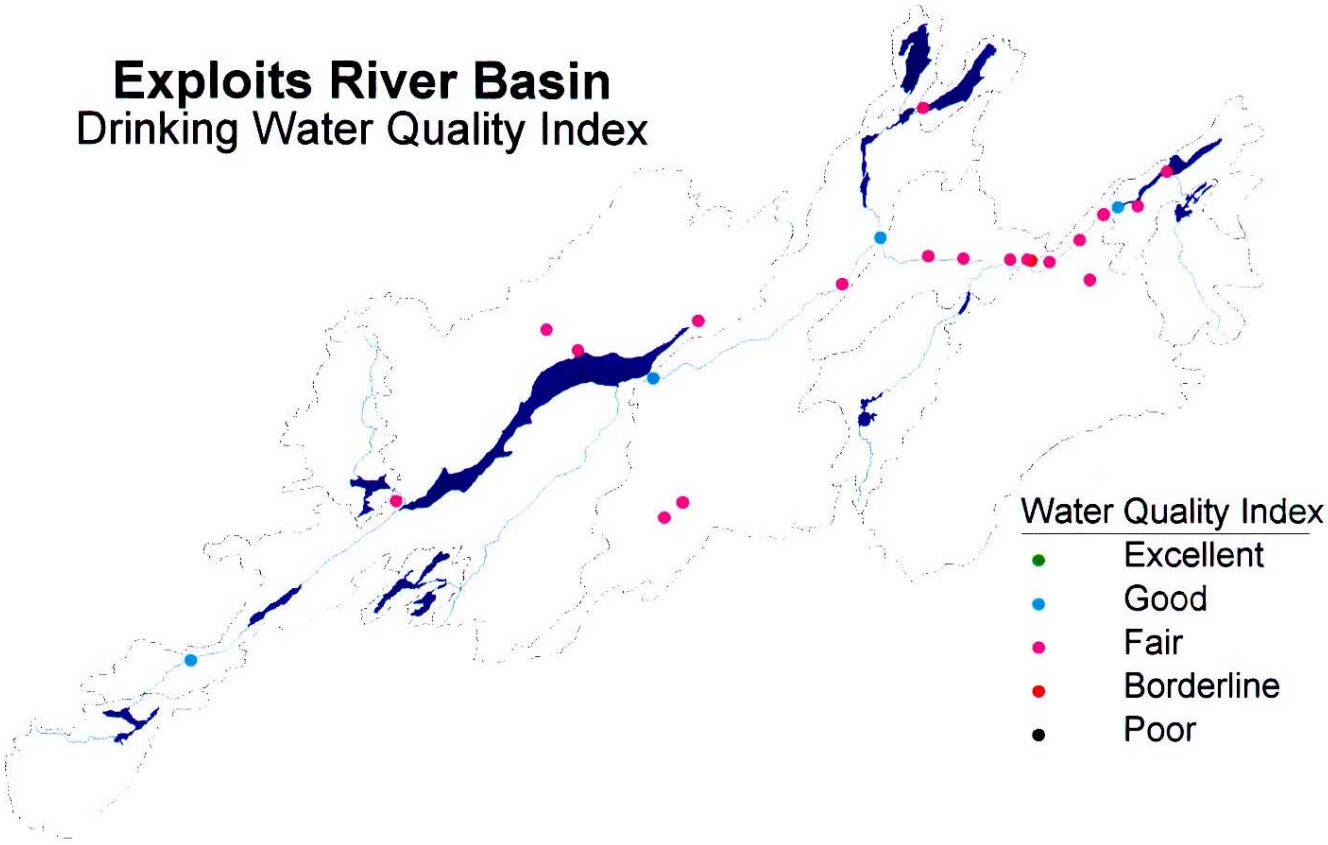
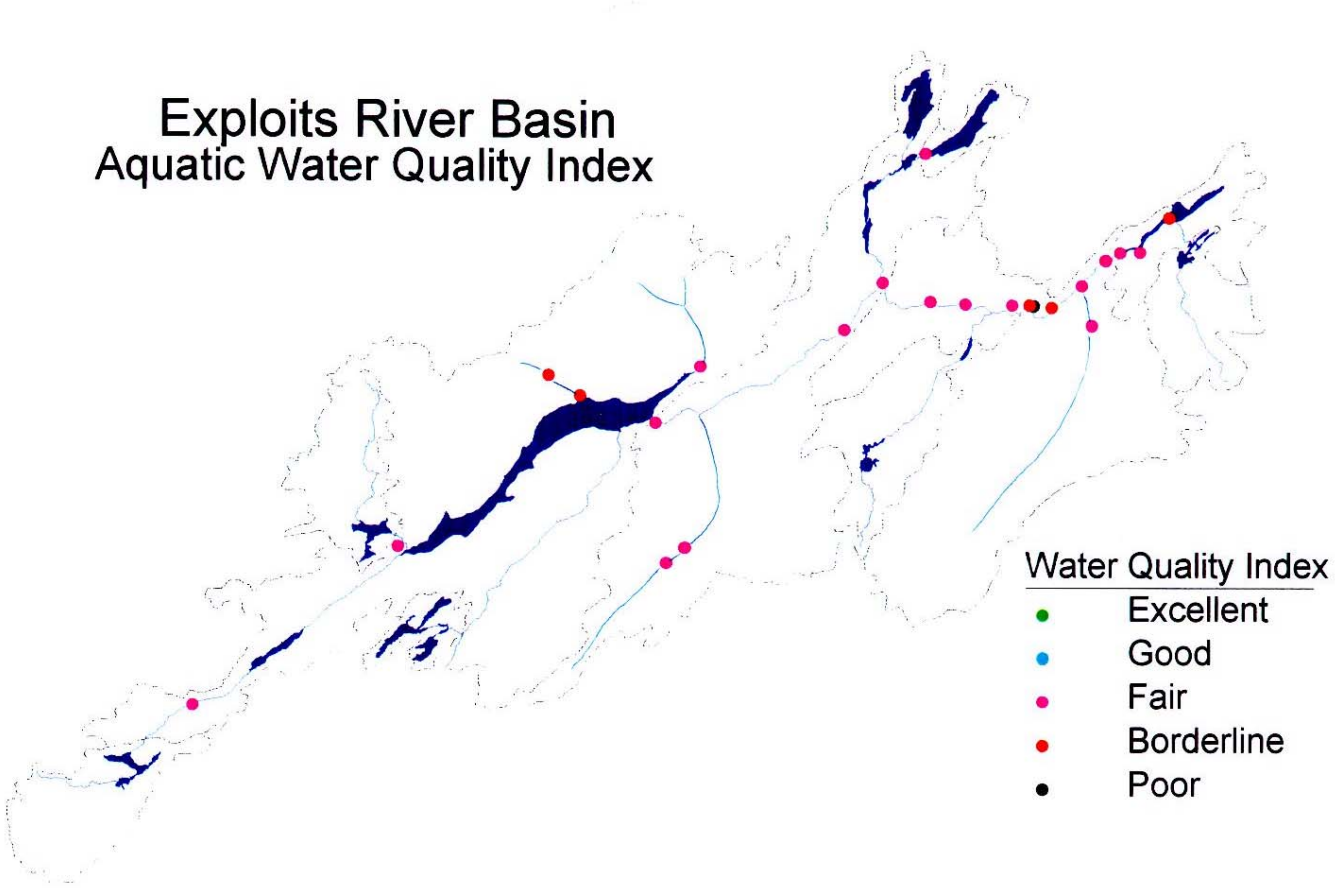


Figure 4. Exploits River Basin: Aquatic Water Quality Index



These long-term stations are Lloyd's River, Exploits River @ Millertown, Exploits River @ Aspen Brook, Exploits River @ Bishops Falls, and Exploits River @ Grand Falls (Figure 5). A closer scrutiny of the data from Exploits River @ Bishops Falls revealed that there was a break in the data collection at the station so the station was dropped from the analysis.

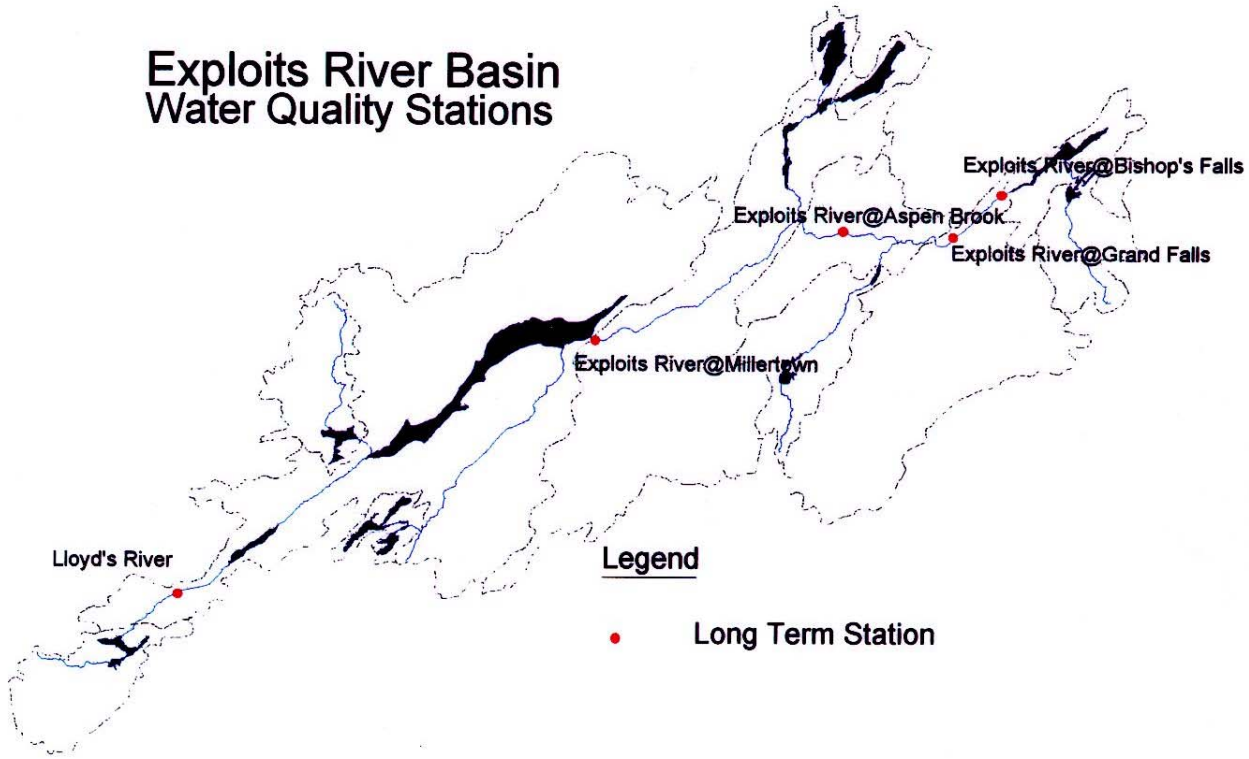
Figures 6, 7, 8, and 9 summarize the water quality trends in Exploits region for the selected four long-term stations with respect to the overall index, drinking water index, and aquatic index respectively.

At Lloyds River (Figure 6) the water quality for all uses shows a marked improvement in 1988 and continues to improve gradually up to 1994. The overall and aquatic index is consistently fair and the drinking water index is good. The water index for Lloyds River continues to be good in the current sampling as noted earlier (Figure 3).

At Exploits River @ Millertown (Figure 7) the water quality does not reflect the same improvement as at Lloyds River. The quality deteriorates significantly up to 1993 but improved in 1994. The current sampling indicates that it has continued to remain stable since (Figures 2, 3, and 4). As for Lloyds River the drinking water index is better than the overall and aquatic index.

At Exploits River @ Grand Falls (Figure 8) the water quality indices reflect a fluctuating water quality. In 1988, 1992 and 1993 the water quality deteriorated but more so for the drinking water index than the overall and aquatic indices. The water quality showed a marked improvement for all indices in 1994 especially for drinking. The current sampling indicates that the overall and aquatic indexes continue to be fair but the drinking index has fallen to fair from excellent (Figures 2, 3, and 4).

Figure 5. Exploits River Basin: Water Quality Stations



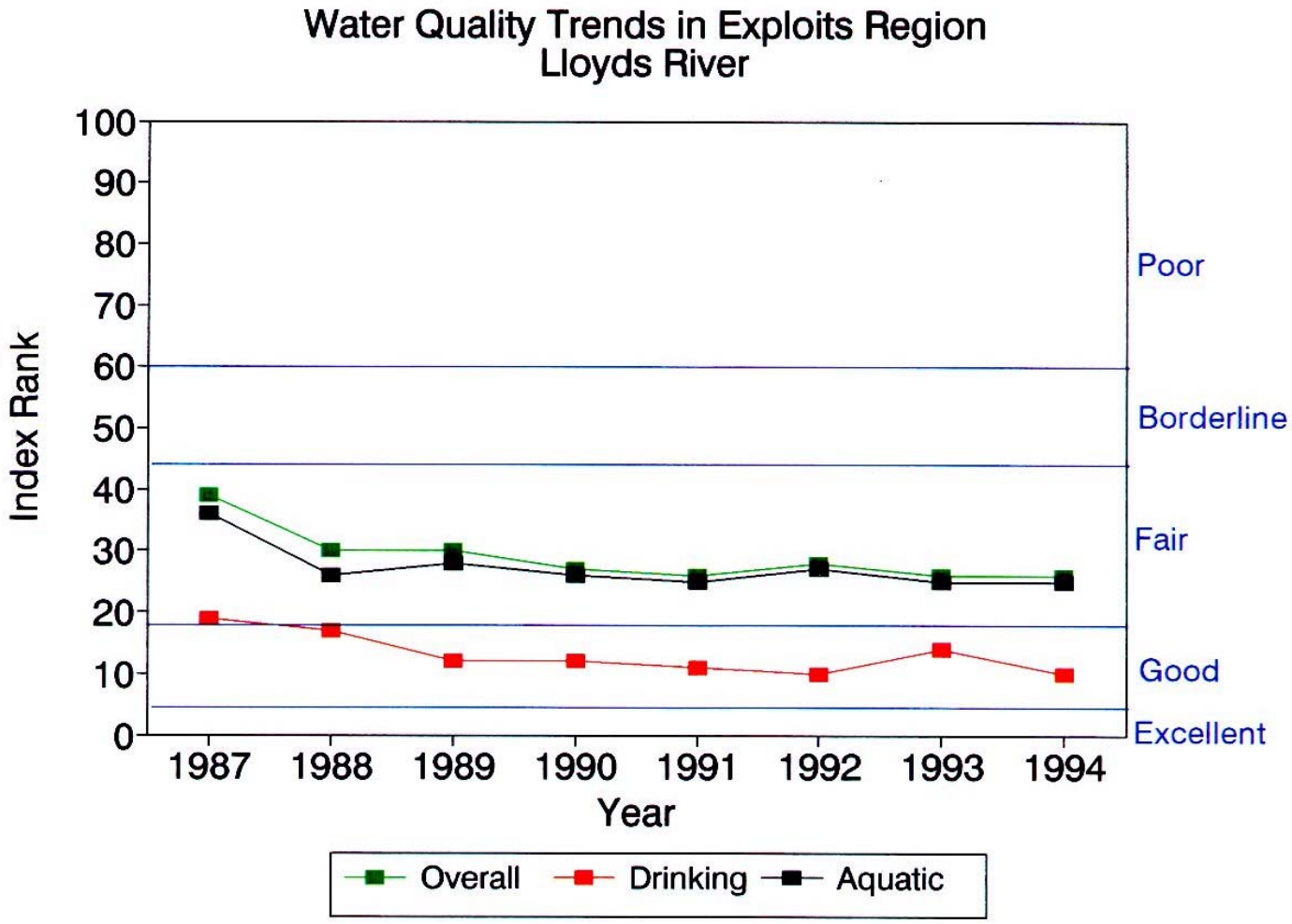


Figure 6. Water Quality Trends in Exploits Region- Lloyds River

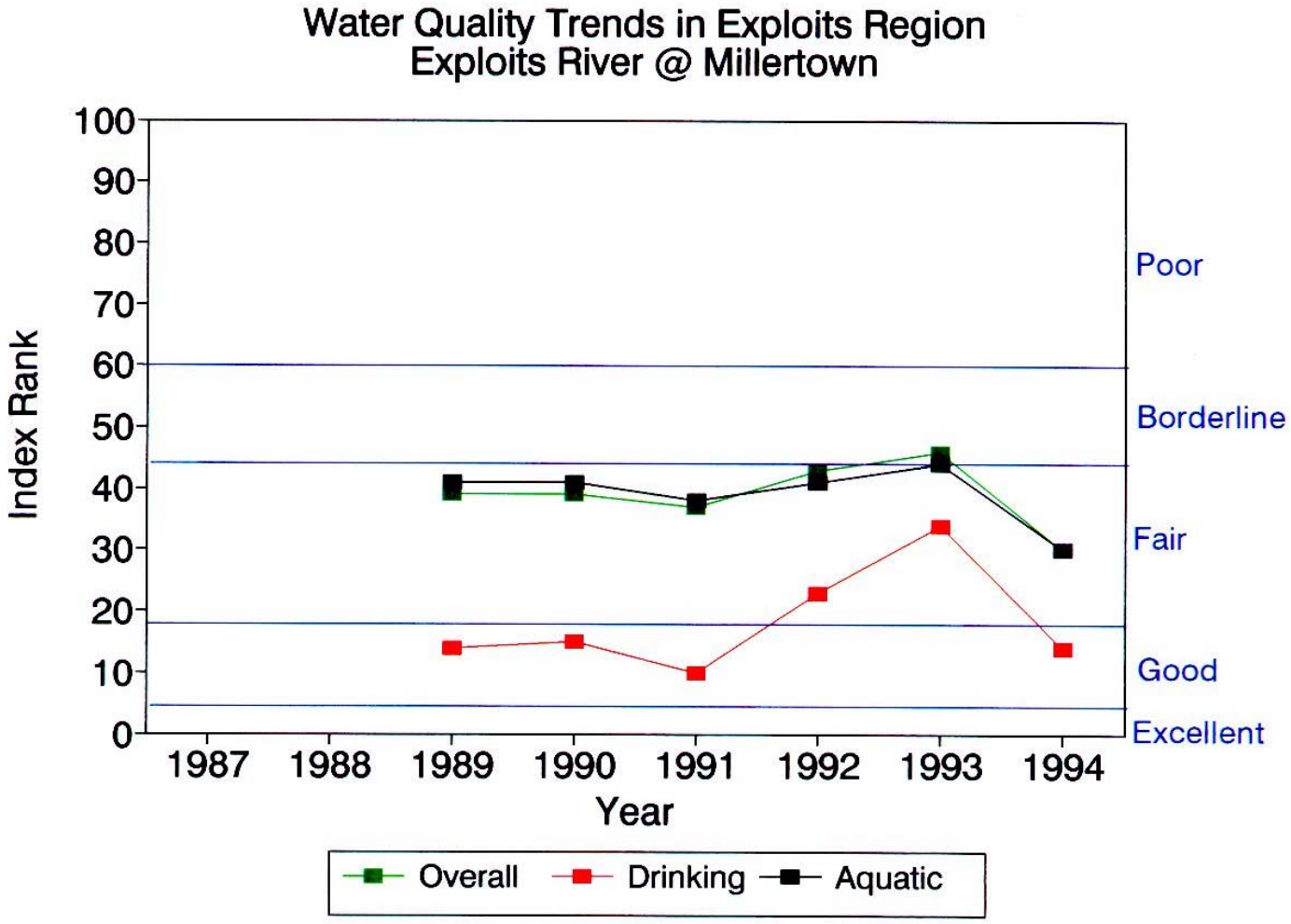


Figure 7. Water Quality Trends in Exploits Region- Exploits River @ Millertown

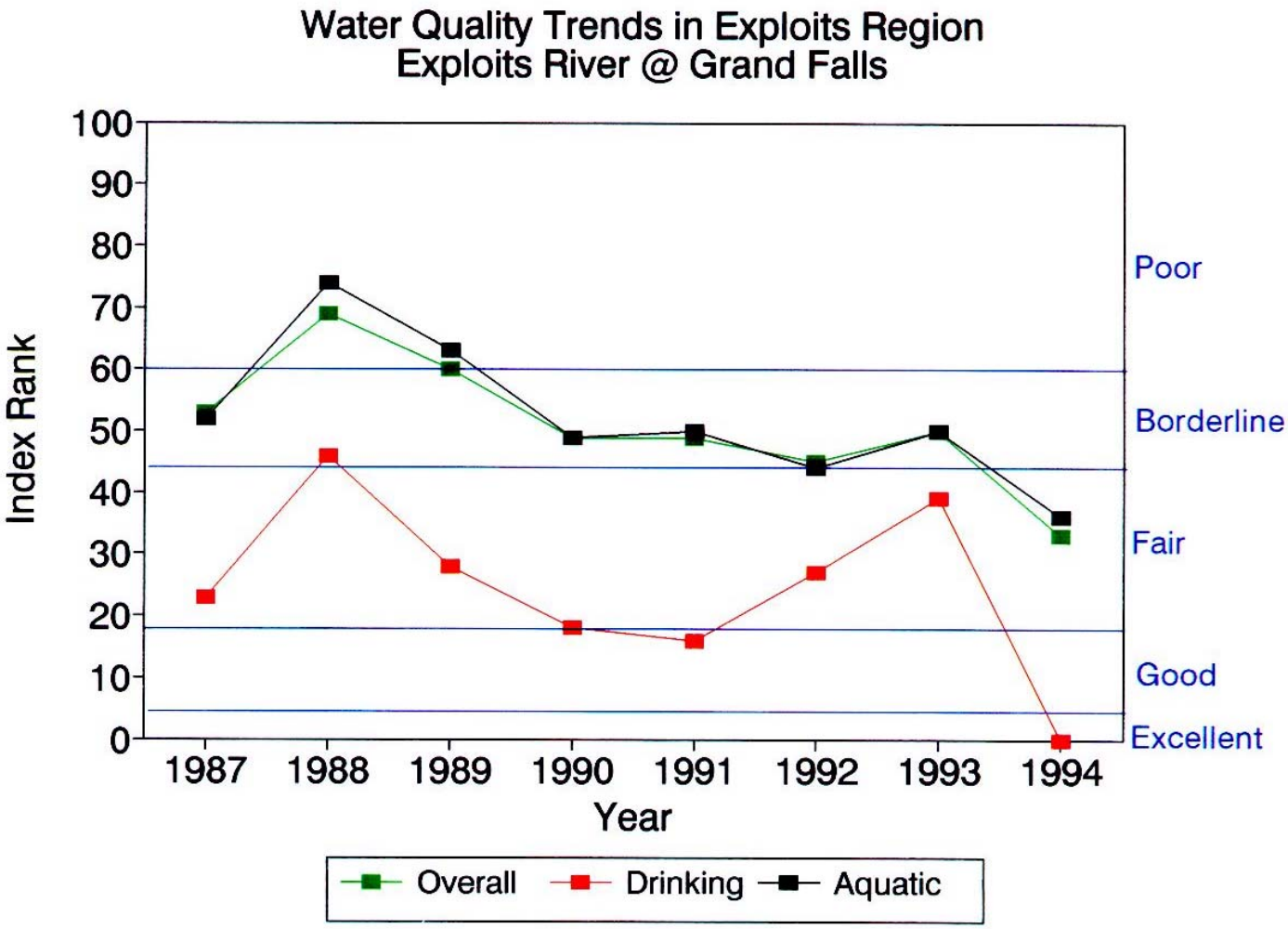


Figure 8. Water Quality Trends in Exploits Region- Exploits River @ Grand Falls

At Exploits River @ Aspen Brook (Figure 9) the water quality indices reflect a fluctuating water quality. In 1990, 1991 and 1992 the water quality deteriorated but more so for the drinking water index than the overall and aquatic indices. The drinking water index fluctuated between good and fair whereas the overall and aquatic indices fluctuated between borderline and fair. Though the water quality showed a marked improvement for overall and aquatic indices in 1994, the drinking index indicated deterioration in water quality and changed to fair from good. The current sampling indicates that all the indices are fair (Figures 2, 3, and 4).

Figures 10, 11, and 12 present the information presented in Figures 6, 7, 8, and 9 by comparing all four stations simultaneously. Figure 10 and 12 clearly show that the water quality deteriorates progressively as the sampling station move from the upper sub basin to the lower sub basin. In Figure 11, the trend is not as clear due to the fluctuating nature of water quality with respect to drinking water quality especially in 1994.

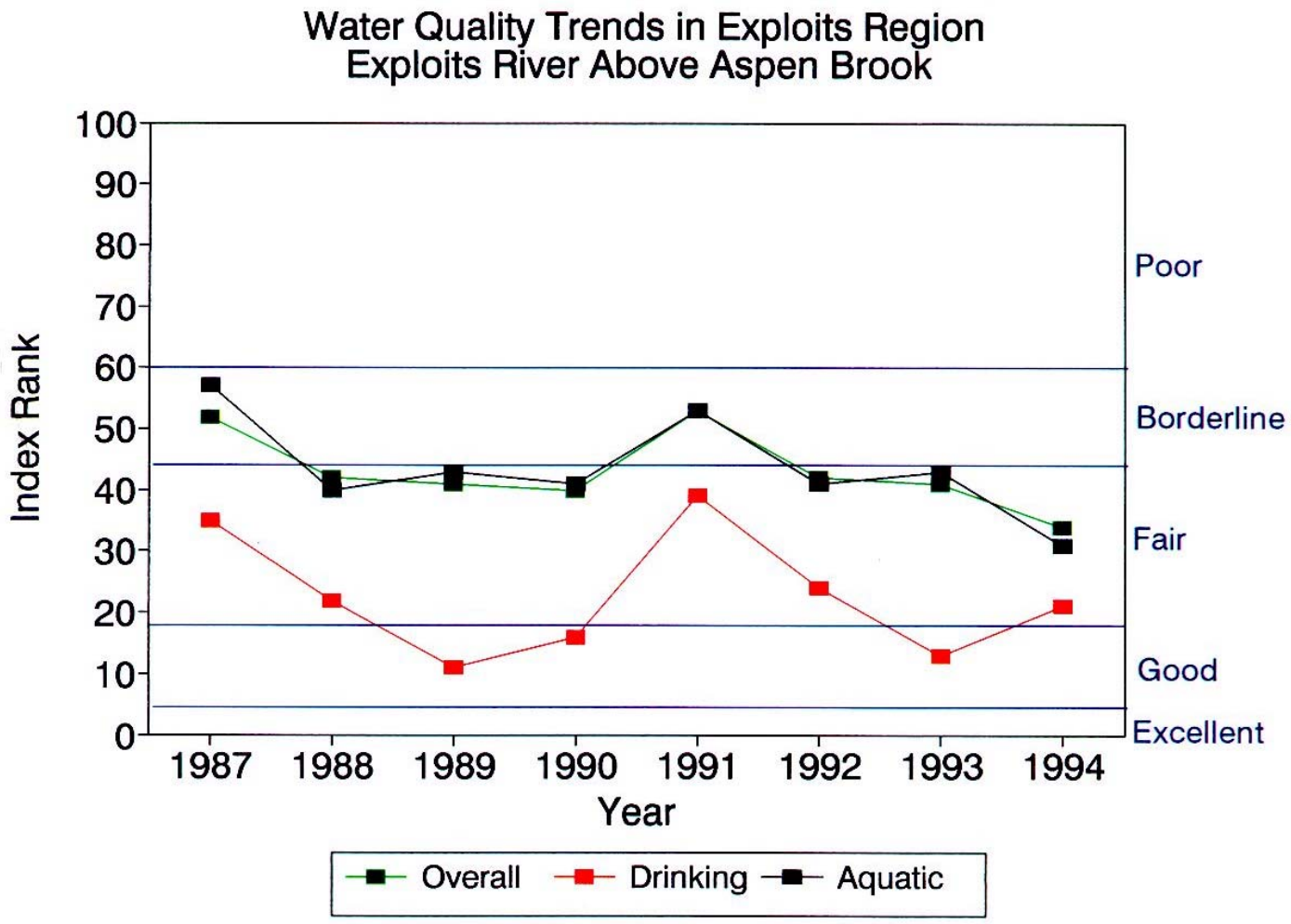


Figure 9. Water Quality Trends in Exploits Region- Exploits River @ Aspen Brook

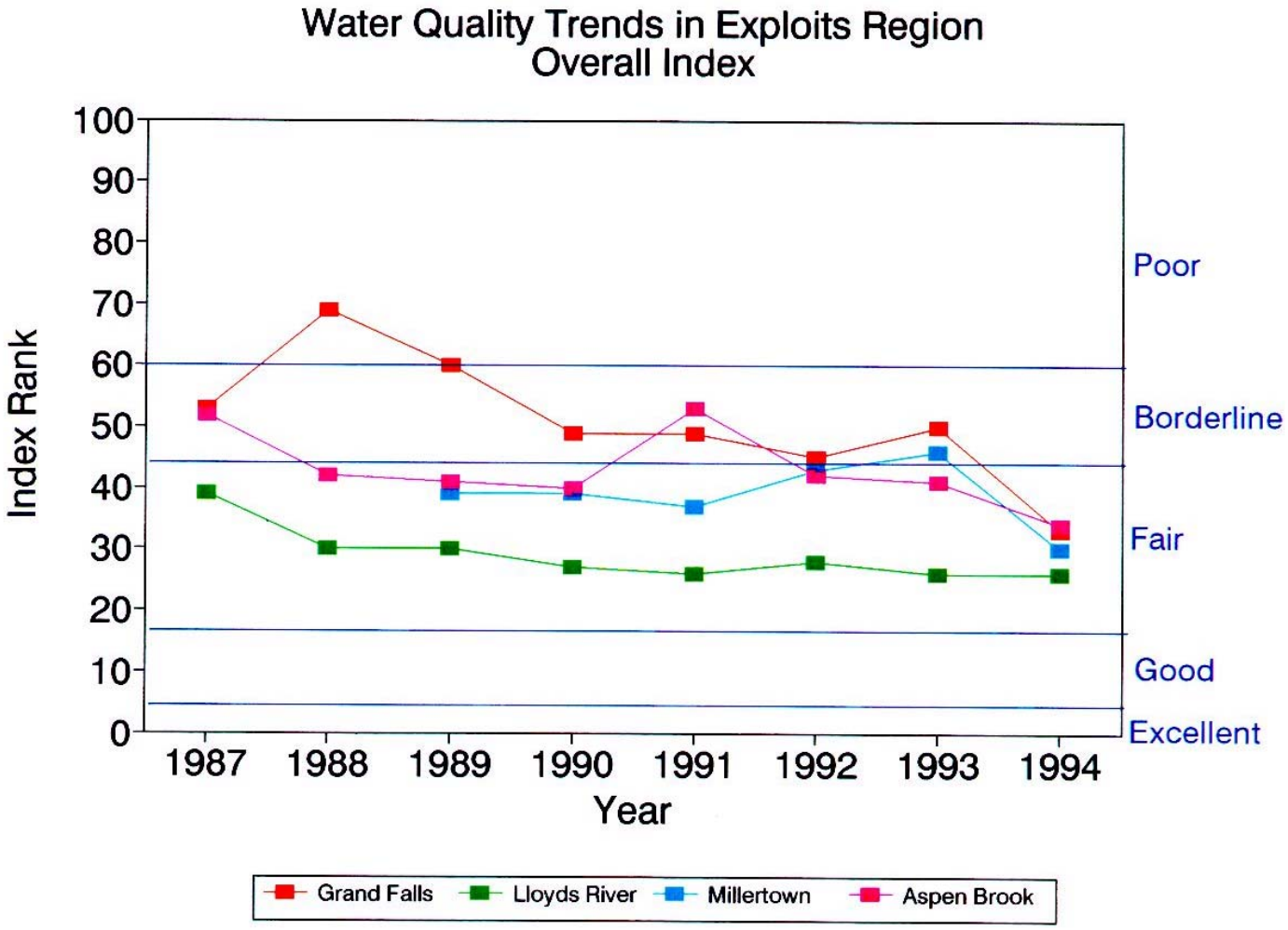


Figure 10. Water Quality Trends in Exploits Region- Overall Index

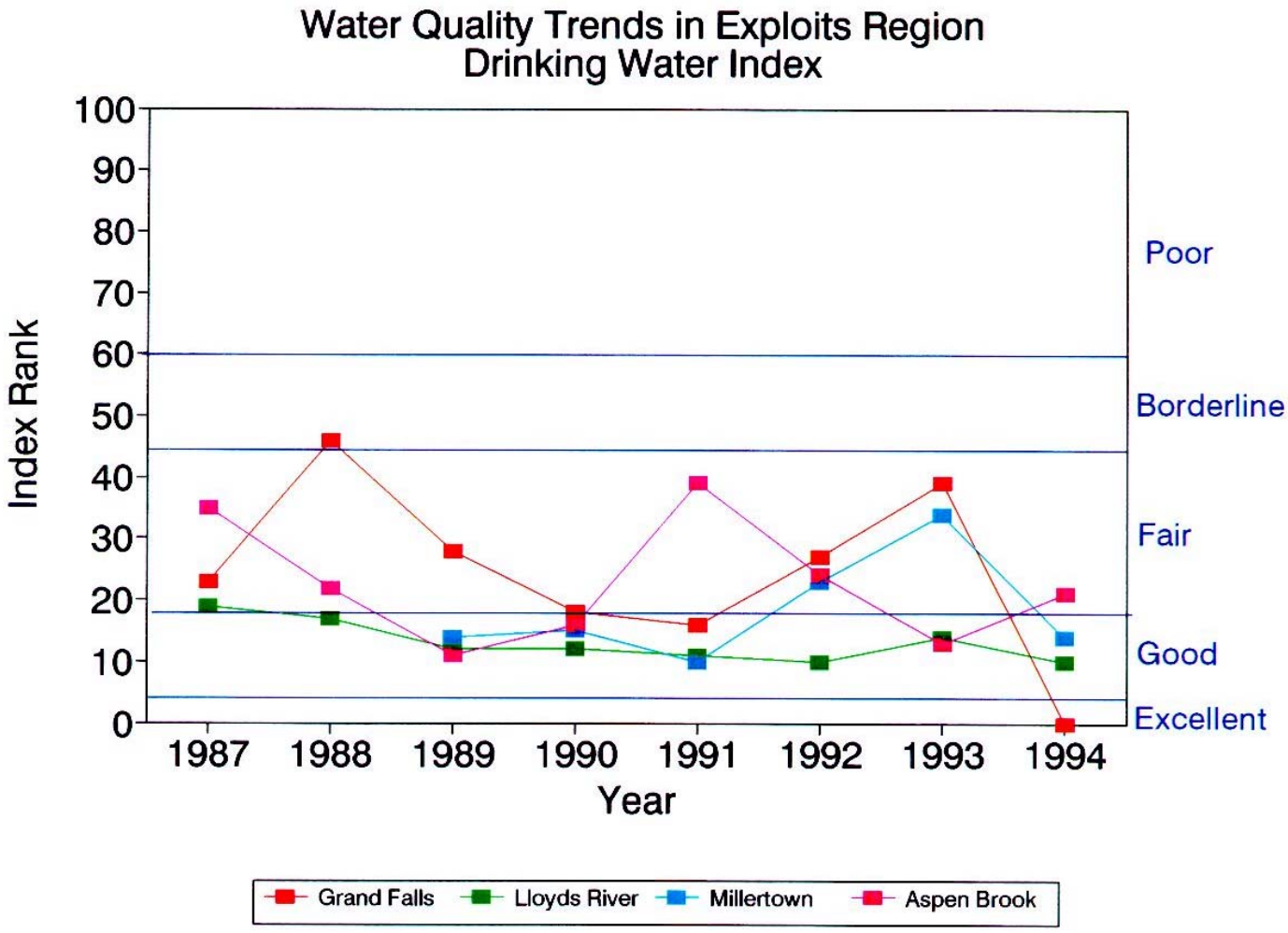


Figure 11. Water Quality Trends in Exploits Region- Drinking Water Index

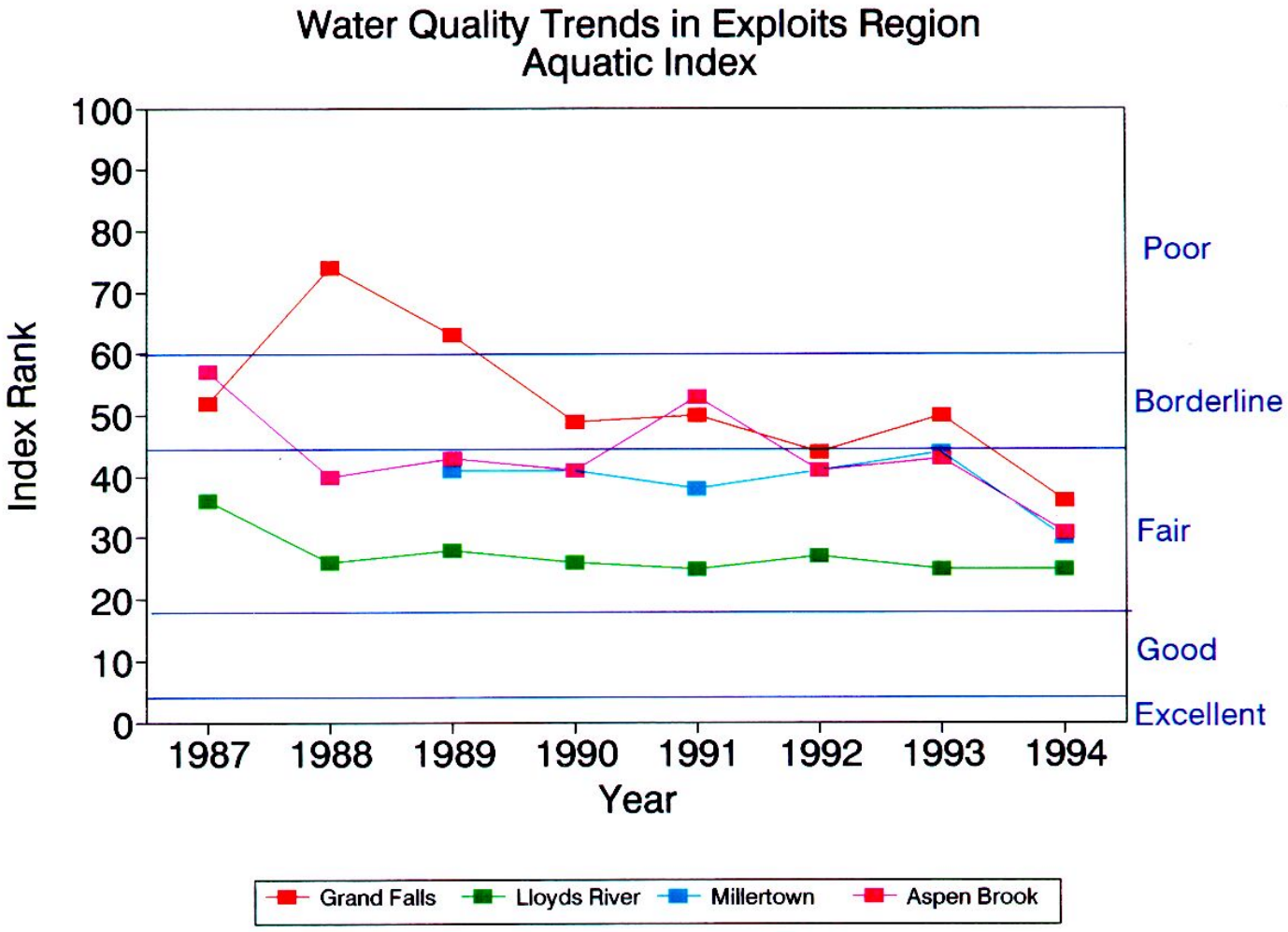


Figure 12. Water Quality Trends in Exploits Region – Aquatic Index

1.4 CONCLUSIONS

The overall water index ranged from borderline to fair at all stations except for Corduroy Brook where it was poor. The aquatic index followed the same pattern. The drinking water index ranged from borderline to fair at all the stations except for four sites (Lloyd's River, Exploits River @ Millertown, Badger Brook, and Exploits River @ Bond Bridge) where it was good.

In addition, with respect to water quality trends, the WQI indicates that the water quality deteriorates progressively as the sampling stations move from the upper sub basin to the lower sub basin. This trend is especially evident for the overall and aquatic indices. For the drinking water index, the trend is not as clear due to the fluctuating nature of water quality with respect to drinking water quality especially in 1994.