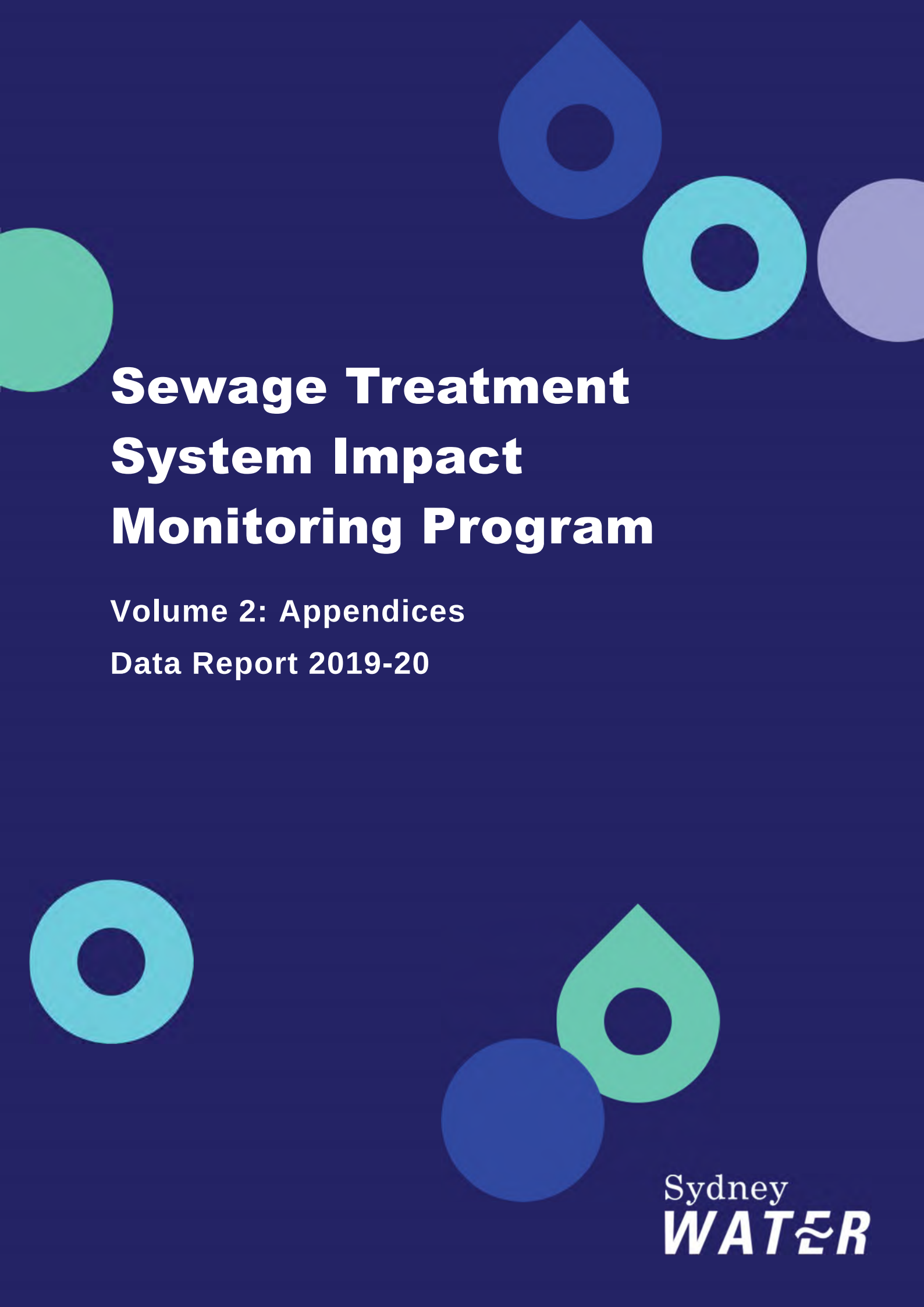




Sewage Treatment System Impact Monitoring Program

**Volume 2: Appendices
Data Report 2019-20**

Sydney
WATER



Commercial-in-Confidence

Sydney Water

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Contents

Appendix A : Glossary	1
Appendix B : List of rainfall stations and location details.....	4
Appendix C : Trends in discharge and reuse volumes, discharge quality and pollutant loads from coastal WWTPs.....	10
Warriewood WWTP.....	11
North Head WWTP	16
Bondi WWTP	24
Malabar WWTP.....	33
Cronulla WWTP	41
Wollongong WWTP.....	52
Shellharbour WWTP	58
Bombo WWTP	65
Malabar storm WWTPs (Fairfield, Glenfield and Liverpool)	72
Appendix D: Trends in discharge and reuse volumes, discharge quality and pollutant loads from inland WWTPs.....	78
Picton WWTP.....	79
West Camden WWTP	92
Wallacia WWTP	102
Penrith WWTP	109
Winmalee WWTP	122
North Richmond WWTP	131
Richmond WWTP.....	140
St Marys WWTP.....	150
Quakers Hill WWTP	162
Riverstone WWTP.....	175
Castle Hill WWTP.....	184
Rouse Hill WWTP	194
Hornsby Heights WWTP	203
West Hornsby WWTP	212
Brooklyn WWTP.....	219
Appendix E : Wastewater overflows	223
Dry weather overflows.....	223
Wet weather overflows.....	225
Appendix F : Ocean receiving water	227
Appendix G : Ocean sediment program	228
Appendix H : Harbour and beaches	229
Sydney Beaches: Northern Sydney.....	231
Sydney Beaches: Central Sydney	239
Sydney Beaches: Southern Sydney	243
Illawarra Beaches: Wollongong	246
Illawarra Beaches: Shellharbour.....	250
Illawarra Beaches: Bombo	251
Sydney Harbour and Estuaries: Botany Bay and Georges River	253
Sydney Harbour and Estuaries: Port Hacking	259
Sydney Harbour and Estuaries: Port Jackson	261
Sydney Harbour and Estuaries: Middle Harbour.....	266

Sydney Harbour and Estuaries: Pittwater	270
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Appendix I : Chlorophyll-a trends at estuarine sites 278

Port Jackson	278
Botany Bay.....	281
Port Hacking	283

Appendix J : Water quality trends in lagoons 284

Appendix K : Intertidal communities – Shoreline outfalls 292

Intertidal communities Shellharbour 2008 to 2019	296
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Appendix L : Intertidal communities of Sydney’s estuaries..... 306

Intertidal rock platform communities	306
Settlement panels	309

Appendix M : Hawkesbury-Nepean River water quality trends 311

N92: Nepean River at Maldon Weir	312
N75: Nepean River at Sharpes Weir	318
N67: Nepean River at Wallacia Bridge	324
N57: Nepean River at Penrith Weir	330
N51: Nepean River opposite Fitzgerald Creek	336
N48A: Nepean River at Smith Road	342
N44: Nepean River at Yarramundi Bridge	348
N42: Hawkesbury River at North Richmond	354
N39: Hawkesbury River at Freemans Reach.....	360
NS04A: Lower South Creek at Fitzroy Bridge.....	366
N35: Hawkesbury River at Wilberforce.....	372
NC11A: Lower Cattai Creek at Cattai Ridge Road	378
N3001: Hawkesbury River off Cattai SRA	384
N26: Hawkesbury River at Sackville Ferry.....	390
N2202: Lower Colo River at Putty Road	396
N18: Hawkesbury River at Leets Vale	402
NB13: Berowra Creek at Calabash Bay	408
NB11: Berowra Creek off Square Bay	414

Appendix N : Stream health of Hawkesbury-Nepean River 420

Stream health near Picton WWTP.....	421
Stream health near West Camden WWTP	422
Stream health near Wallacia WWTP	435
Stream health near Penrith WWTP	436
Stream health and community structure of the unnamed creek and the Nepean River near Winmalee WWTP	438
Stream health near North Richmond WWTP	461
Stream health near St Mary’s WWTP.....	463
Stream health near Quakers Hill WWTP	464
Stream health near Riverstone WWTP.....	465
Stream health near Castle Hill WWTP.....	466
Stream health near Rouse Hill WWTP	467
Stream health near Hornsby Heights WWTP	468
Stream health near West Hornsby WWTP	479

Appendix O : Stream health of other Sydney rivers 492

List of figures

Figure B-1	Rainfall stations used for categorising wastewater data as dry or wet weather days	8
Figure B-2	Rainfall stations used for categorising receiving water quality data as dry or wet weather days	9
Figure K-1	Barrack Point with a healthy intertidal rock platform community in 2019	295
Figure K-2	Barrack Point (in 2001) with an unhealthy intertidal rock platform community impacted by wastewater discharges from the Shellharbour WWTP prior to upgrade in the early to mid 2000's	295
Figure K-3	Two-dimensional nMDS ordination plot of 2008 to 2019 intertidal rock platform community data	298
Figure K-4	Three-dimensional nMDS ordination plot of 2008 to 2019 intertidal rock platform community data	298
Figure K-5	PCO ordination plot of 2008 to 2019 intertidal rock platform community data -dimensional ..	299
Figure K-6	CAP ordination plot of intertidal rock platform community data (2008 to 2018 for Control site 1 and Control site 2 and 2008 to 2018 outfall site) with 2019 outfall samples (orange squares) predicted	299
Figure L-1	Relatively lower salinity zone with year plotted against Principal Coordinates Analysis axis 1 of distance among centroids for sites	307
Figure L-2	Relatively higher salinity zone with year plotted against Principal Coordinates Analysis axis 1 of distance among centroids for sites	308
Figure L-3	Multiple mean comparison groupings of relatively high salinity locations for 2019-20. (means covered by the same bar are not significantly different)	309
Figure L-4	Multiple mean comparison groupings of relatively lower salinity locations for 2019-20. (means covered by the same bar are not significantly different)	310
Figure N-1	Stream health of Nepean River near Picton WWTP	421
Figure N-2	Stream health of Matahil Creek near West Camden WWTP	422
Figure N-3	Stream health of the Nepean River near West Camden WWTP	423
Figure N-4	Two-dimensional ordination plot of freshwater macroinvertebrate edge habitat community structure of Matahil Creek upstream and downstream sites of West Camden WWTP	425
Figure N-5	Tree diagram of freshwater macroinvertebrate edge habitat community structure of Matahil Creek upstream and downstream sites of West Camden WWTP	425
Figure N-6	Shade plot of freshwater macroinvertebrate edge habitat community structure of Matahil Creek upstream and downstream sites of West Camden WWTP	428
Figure N-7	Dimensions 1 and 2 of three-dimensional ordination plot of freshwater macroinvertebrate edge habitat community structure of sites upstream-downstream of Nepean River at the confluence of Matahil Creek into which West Camden WWTP discharges	430
Figure N-8	Tree diagram of freshwater macroinvertebrate edge habitat community structure of sites upstream-downstream of Nepean River at the confluence of Matahil Creek into which West Camden WWTP discharges	430
Figure N-9	Shade plot of freshwater macroinvertebrate edge habitat community structure of upstream-downstream sites of Nepean River at the confluence of Matahil Creek into which West Camden WWTP discharges	434
Figure N-10	Stream health of Warragamba River near Wallacia WWTP	435
Figure N-11	Stream health of Boundary Creek near Penrith WWTP	436
Figure N-12	Stream health of the Nepean River upstream-downstream of the confluence of Boundary Creek near Penrith WWTP	437
Figure N-13	Stream health of unnamed creek below Winmalee WWTP for two downstream sites	438
Figure N-14	Stream health of the Nepean River near Winmalee WWTP	439

Figure N-15 Dimensions 1 and 3 of three-dimensional ordination plot of freshwater macroinvertebrate edge habitat community structure of both downstream sites of unnamed creek below Winmalee WWTP	442
Figure N-16 Dimensions 1 and 2 of three-dimensional ordination plot of freshwater macroinvertebrate riffle habitat community structure of both downstream sites of unnamed creek below Winmalee WWTP	442
Figure N-17 Tree diagram of freshwater macroinvertebrate edge habitat community structure of both downstream sites of unnamed creek below Winmalee WWTP	443
Figure N-18 Tree diagram of freshwater macroinvertebrate riffle habitat community structure of both downstream sites of unnamed creek below Winmalee WWTP	443
Figure N-19 Shade plot of freshwater macroinvertebrate edge habitat community structure of both downstream sites of unnamed creek below Winmalee WWTP	449
Figure N-20 Shade plot of freshwater macroinvertebrate riffle habitat community structure of both downstream sites of unnamed creek below Winmalee WWTP	450
Figure N-21 Dimensions 1 and 3 of three-dimensional nMDS ordination plot of freshwater macroinvertebrate macrophyte habitat community structure of sites upstream-downstream of Nepean River at the confluence of the unnamed creek into which Winmalee WWTP discharges.....	452
Figure N-22 Dimensions 1 and 3 of three-dimensional ordination plot of freshwater macroinvertebrate edge habitat community structure of sites upstream-downstream of Nepean River at the confluence of the unnamed creek into which Winmalee WWTP discharges	452
Figure N-23 Tree diagram of freshwater macroinvertebrate macrophyte habitat community structure of sites upstream-downstream of Nepean River at the confluence of the unnamed creek into which Winmalee WWTP discharges.....	453
Figure N-24 Tree diagram of freshwater macroinvertebrate edge habitat community structure of sites upstream-downstream of Nepean River at the confluence of the unnamed creek into which Winmalee WWTP discharges	453
Figure N-25 Shade plot of freshwater macroinvertebrate macrophyte habitat community structure of upstream-downstream sites of Nepean River at the confluence of the unnamed creek into which Winmalee WWTP discharges.....	459
Figure N-26 Shade plot of freshwater macroinvertebrate edge habitat community structure of upstream-downstream sites of Nepean River at the confluence of the unnamed creek into which Winmalee WWTP discharges	460
Figure N-27 Stream health of Hawkesbury River upstream-downstream of the confluence of Redbank Creek near North Richmond WWTP.....	461
Figure N-28 Stream health of Redbank Creek near North Richmond WWTP	462
Figure N-29 Stream health of South Creek near St Mary's WWTP	463
Figure N-30 Stream health of Breakfast Creek near Quakers Hill WWTP	464
Figure N-31 Stream health of Eastern Creek near Riverstone WWTP	465
Figure N-32 Stream health of Cattai Creek near Castle Hill WWTP	466
Figure N-33 Stream health of Second Ponds Creek near Rouse Hill WWTP	467
Figure N-34 Stream health of Calna Creek near Hornsby Heights WWTP.....	468
Figure N-35 Dimensions 1 and 3 of three-dimensional ordination plot of freshwater macroinvertebrate edge habitat community structure of upstream-downstream sites of Calna Creek near Hornsby Heights WWTP	470
Figure N-36 Dimensions 1 and 2 of three-dimensional ordination plot of freshwater macroinvertebrate riffle habitat community structure of upstream-downstream sites of Calna Creek near Hornsby Heights WWTP	471
Figure N-37 Tree diagram of freshwater macroinvertebrate edge habitat community structure of upstream-downstream sites of Calna Creek near Hornsby Heights WWTP.....	471
Figure N-38 Tree diagram of freshwater macroinvertebrate riffle habitat community structure of upstream-downstream sites of Calna Creek near Hornsby Heights WWTP	472

Figure N-39 Shade plot of freshwater macroinvertebrate edge habitat community structure of upstream-downstream sites of Calna Creek near Hornsby Heights WWTP	477
Figure N-40 Shade plot of freshwater macroinvertebrate riffle habitat community structure of upstream-downstream sites of Calna Creek near Hornsby Heights WWTP	478
Figure N-41 Stream health of Waitara Creek near West Hornsby WWTP	479
Figure N-42 Dimensions 1 and 2 of three-dimensional ordination plot of freshwater macroinvertebrate edge habitat community structure of upstream-downstream sites of Waitara Creek near West Hornsby WWTP	481
Figure N-43 Dimensions 1 and 2 of three-dimensional ordination plot of freshwater macroinvertebrate pool rock habitat community structure of upstream-downstream sites of Waitara Creek near West Hornsby WWTP	481
Figure N-44 Tree diagram of freshwater macroinvertebrate edge habitat community structure of upstream-downstream sites of Waitara Creek near West Hornsby WWTP	482
Figure N-45 Tree diagram of freshwater macroinvertebrate pool rock habitat community structure of upstream-downstream sites of Waitara Creek near West Hornsby WWTP	482
Figure N-46 Shade plot of freshwater macroinvertebrate edge habitat community structure of upstream-downstream sites of Waitara Creek near West Hornsby WWTP	488
Figure N-47 Shade plot of freshwater macroinvertebrate pool rock habitat community structure of upstream-downstream sites of Waitara Creek near West Hornsby WWTP	489
Figure O-1 Stream health of Lane Cove and Parramatta rivers in comparison to control sites	493
Figure O-2 Stream health of lower freshwater Georges River sites compared to control sites in the upper Georges River system	493

List of tables

Table B-1	Rainfall stations used for categorising wastewater data as dry or wet weather days	4
Table B-2	Rainfall stations used for categorising receiving water quality data as dry or wet weather days.....	6
Table E-1	Trend in dry weather wastewater overflow frequency and volumes for coastal WWTPs wastewater system (2013-14 to 2019-20)	223
Table E-2	Trend in dry weather wastewater overflow frequency and volumes for inland wastewater systems (2013-14 to 2019-20).....	224
Table E-3	Trend in wet weather wastewater overflow frequency and volumes for ocean WWTPs wastewater system (2013-14 to 2019-20)	225
Table E-4	Trend in wet weather wastewater overflow frequency and volumes for inland WWTPs wastewater system (2013-14 to 2019-20)	226
Table H-1.	Short-listed dry weather <i>Enterococci</i> exceptions data (>35 cfu/100mL) based on catchment rainfall condition (2019-20)	274
Table K-1	Asymmetrical PERMANOVA of 2019 intertidal assemblages	293
Table K-2	SIMPER 2019 - intertidal assemblages by site	294
Table K-3	Asymmetrical PERMANOVA of 2008 to 2019 intertidal assemblages	300
Table K-4	CAP analysis of 2008 to 2018 intertidal assemblages with 2019 outfall site samples predicted	301
Table N-1	t-test of upstream-downstream SIGNAL-SG scores of 2019-20 samples from the Nepean River near Picton WWTP	421
Table N-2	t-test of upstream-downstream SIGNAL-SG scores of 2019-20 samples from Matahil Creek near West Camden WWTP	422
Table N-3	t-test of upstream-downstream SIGNAL-SG scores of 2019-20 samples from the Nepean River near West Camden WWTP	423
Table N-4	ANOSIM test of 'Site' factor for edge habitat of Matahil Creek upstream and downstream sites of West Camden WWTP	426
Table N-5	PERMANOVA test of 'Site' and 'Year' factors for edge habitat of Matahil Creek upstream and downstream sites of West Camden WWTP	426
Table N-6	PERMDISP test of 'Site' factor for edge habitat of Matahil Creek upstream and downstream sites of West Camden WWTP	426
Table N-7	ANOSIM test of 'Site period' samples for edge habitat of Matahil Creek upstream and downstream sites of West Camden WWTP	427
Table N-8	Genera subset whose multivariate pattern matches full genera set of the edge habitat of Matahil Creek upstream and downstream sites of West Camden WWTP	427
Table N-9	ANOSIM test of Site for edge habitat of upstream-downstream sites of Nepean River at the confluence of Matahil Creek into which West Camden WWTP discharges	431
Table N-10	PERMANOVA test of Site and Year factors for edge habitat of upstream-downstream sites of Nepean River at the confluence of Matahil Creek into which West Camden WWTP discharges	431
Table N-11	PERMDISP test of Site for edge habitat of upstream-downstream sites of Nepean River at the confluence of Matahil Creek into which West Camden WWTP discharges	431
Table N-12	ANOSIM test of Site period for edge habitat of upstream-downstream sites of Nepean River at the confluence of Matahil Creek into which West Camden WWTP discharges	432
Table N-13	Genera subset whose multivariate pattern matches full genera set of the edge habitat of upstream-downstream sites of Nepean River at the confluence of Matahil Creek into which West Camden WWTP discharges	433
Table N-14	t-test of upstream-downstream SIGNAL-SG scores of 2019-20 samples from the Warragamba River near Wallacia WWTP	435
Table N-15	t-test of upstream-downstream SIGNAL-SG scores of 2019-20 samples from Boundary Creek near Penrith WWTP	437

Table N-16	t-test of upstream-downstream SIGNAL-SG scores of 2019-20 samples from the Nepean River near Penrith WWTP.....	437
Table N-17	t-test of both downstream site SIGNAL-SG scores from 2019-20 for unnamed creek below Winmalee WWTP	439
Table N-18	t-test of upstream-downstream SIGNAL-SG scores from 2019-20 for the Nepean River near Winmalee WWTP	439
Table N-19	ANOSIM test of 'Site' factor for edge habitat unnamed creek near Winmalee WWTP	444
Table N-20	ANOSIM test of 'Site' factor for riffle habitat unnamed creek below Winmalee WWTP	444
Table N-21	PERMANOVA test of 'Site' and 'Year' factors for edge habitat unnamed creek below Winmalee WWTP	445
Table N-22	PERMANOVA test of 'Site' and 'Year' factors for riffle habitat unnamed creek below Winmalee WWTP	445
Table N-23	PERMDISP test of 'Site' factor for edge habitat unnamed creek below Winmalee WWTP	446
Table N-24	PERMDISP test of 'Site' factor for riffle habitat unnamed creek below Winmalee WWTP	446
Table N-25	ANOSIM test of 'Site period' samples for edge habitat unnamed creek below Winmalee WWTP	447
Table N-26	ANOSIM test of 'Site period' samples for riffle habitat unnamed creek below Winmalee WWTP	447
Table N-27	Genera subset whose multivariate pattern matches full genera set of the edge habitat unnamed creek below Winmalee WWTP	448
Table N-28	Genera subset whose multivariate pattern matches full genera set of the riffle habitat unnamed creek below Winmalee WWTP	448
Table N-29	ANOSIM test of Site for macrophyte habitat of upstream-downstream sites of Nepean River at the confluence of the unnamed creek into which Winmalee WWTP discharges	454
Table N-30	ANOSIM test of Site for edge habitat Nepean River at the confluence of the unnamed creek into which Winmalee WWTP discharges	454
Table N-31	PERMANOVA test of Site and Year factors for macrophyte habitat of upstream-downstream sites of Nepean River at the confluence of the unnamed creek into which Winmalee WWTP discharges.....	455
Table N-32	PERMANOVA test of Site and Year factors for edge habitat of upstream-downstream sites of Nepean River at the confluence of the unnamed creek into which Winmalee WWTP discharges.....	455
Table N-33	PERMDISP test of Site for macrophyte habitat of upstream-downstream sites of Nepean River at the confluence of the unnamed creek into which Winmalee WWTP discharges	456
Table N-34	PERMDISP test of Site for edge habitat of upstream-downstream sites of Nepean River at the confluence of the unnamed creek into which Winmalee WWTP discharges	456
Table N-35	ANOSIM test of Site period for macrophyte habitat of upstream-downstream sites of Nepean River at the confluence of the unnamed creek into which Winmalee WWTP discharges.....	457
Table N-36	ANOSIM test of Site period for edge habitat of upstream-downstream sites of Nepean River at the confluence of the unnamed creek into which Winmalee WWTP discharges	457
Table N-37	Genera subset whose multivariate pattern matches full genera set of the macrophyte habitat of upstream-downstream sites of Nepean River at the confluence of the unnamed creek into which Winmalee WWTP discharges.....	458
Table N-38	Genera subset whose multivariate pattern matches full genera set of the edge habitat of upstream-downstream sites of Nepean River at the confluence of the unnamed creek into which Winmalee WWTP discharges.....	458
Table N-39	t-test of upstream-downstream SIGNAL-SG scores of 2019-20 samples from the Hawkesbury River near North Richmond WWTP	462
Table N-40	t-test of upstream-downstream SIGNAL-SG scores of 2019-20 samples from Redbank Creek near North Richmond WWTP	462
Table N-41	t-test of upstream-downstream SIGNAL-SG scores of 2019-20 samples from South Creek near St Mary's WWTP	463

Table N-42	t-test of upstream-downstream SIGNAL-SG scores of 2019-20 samples from Breakfast Creek near Quakers Hill WWTP	464
Table N-43	t-test of upstream-downstream SIGNAL-SG scores of 2019-20 samples from Eastern Creek near Riverstone WWTP	465
Table N-44	t-test of upstream-downstream SIGNAL-SG scores of 2019-20 samples from Cattai Creek near Castle Hill WWTP	466
Table N-45	t-test of upstream-downstream SIGNAL-SG scores of 2019-20 samples from Second Ponds Creek near Rouse Hill WWTP	467
Table N-46	t-test of upstream-downstream SIGNAL-SG scores of 2019-20 samples from Calna Creek near Hornsby Heights WWTP	468
Table N-47	ANOSIM test of 'Site' factor for edge habitat of Calna Creek near Hornsby Heights WWTP	472
Table N-48	ANOSIM test of 'Site' factor for riffle habitat of Calna Creek near Hornsby Heights WWTP	472
Table N-49	PERMANOVA test of 'Site' and 'Year' factors for edge habitat of Calna Creek near Hornsby Heights WWTP	473
Table N-50	PERMANOVA test of 'Site' and 'Year' factors for riffle habitat of Calna Creek near Hornsby Heights WWTP	473
Table N-51	PERMDISP test of 'Site' factor for edge habitat of Calna Creek near Hornsby Heights WWTP	474
Table N-52	PERMDISP test of 'Site' factor for riffle habitat of Calna Creek near Hornsby Heights WWTP	474
Table N-53	ANOSIM test of 'Site period' for edge habitat of Calna Creek near Hornsby Heights WWTP	475
Table N-54	ANOSIM test of 'Site period' for riffle habitat of Calna Creek near Hornsby Heights WWTP	475
Table N-55	Genera subset whose multivariate pattern matches full genera set of the edge habitat Calna Creek near Hornsby Heights WWTP	476
Table N-56	Genera subset whose multivariate pattern matches full genera set of the riffle habitat Calna Creek near Hornsby Heights WWTP	476
Table N-57	t-test of upstream-downstream SIGNAL-SG scores of 2019-20 samples from Waitara Creek near West Hornsby WWTP	479
Table N-58	ANOSIM test of 'Site' factor for edge habitat of Waitara Creek near West Hornsby WWTP	483
Table N-59	ANOSIM test of 'Site' factor for pool rock habitat of Waitara Creek near West Hornsby WWTP	483
Table N-60	PERMANOVA test of 'Site' and 'Year' factors for edge habitat of Waitara Creek near West Hornsby WWTP	484
Table N-61	PERMANOVA test of 'Site' and 'Year' factors for pool rock habitat of Waitara Creek near West Hornsby WWTP	484
Table N-62	PERMDISP test of 'Site' factor for edge habitat of Waitara Creek near West Hornsby WWTP	485
Table N-63	PERMDISP test of 'Site' factor for pool rock habitat of Waitara Creek near West Hornsby WWTP	485
Table N-64	ANOSIM test of 'Site period' factor for edge habitat of Waitara Creek near West Hornsby WWTP	486
Table N-65	ANOSIM test of 'Site period' factor for pool rock habitat of Waitara Creek near West Hornsby WWTP	486
Table N-66	Genera subset whose multivariate pattern matches full genera set of the edge habitat of Waitara Creek near West Hornsby WWTP	487
Table N-67	Genera subset whose multivariate pattern matches full genera set of the pool rock habitat of Waitara Creek near West Hornsby WWTP	487

Appendix A : Glossary

Acronyms/ Abbreviations	Full meanings
ADCP	Acoustic Doppler Current Profile
APHA	American Public Health Association
ANOSIM	Analysis of similarities
ANOVA	Analysis of variance
ANZECC	Australian and New Zealand Environment and Conservation Council.
ANZG	Australian and New Zealand Guidelines for Fresh and Marine Water Quality
AWI	Antecedent Wetness Index
AWTP	Advanced Water Treatment Plant
BOM	Bureau of Meteorology
BOOS	Bondi Ocean Outfall Sewer
CAP	Canonical Analysis of Principal coordinates
CBOD	Carbonaceous Biochemical Oxygen Demand
CCTV	Closed-Circuit Television
cfu/100mL	Colony forming units per 100 millilitres
COOS	Cronulla Ocean Outfall Sewer
CRM	Certified reference material
CTD	A CTD or Sonde is an oceanography instrument used to measure the conductivity, temperature, and pressure of seawater (the D stands for "depth," which is closely related to pressure)
DF	Degrees of freedom
DPIE	Department of Planning, Industry and Environment
DWLP	Dry weather leakage program
EC ₅₀	Effect Concentration for immobilization of 50% of exposed target biota
EES	Environment, Energy and Science Branch, NSW DPIE
EMS	Effluent Management Strategy
EOP	Emergency Operations Protocol
EPA	Environment Protection Authority
EPL	Environment Protection Licence
ER	Environmental Response
FOG	Fats, Oils and Grease
FS&T	Field Sampling and Testing
GS	Grain Size
HRC	Healthy River Commission
IOT	Internet Of Things
KL	Kilolitre
km	kilometre(s)
m	metre
MOF	Maximum overflow frequency
Maximum	Maximum value of set of observations

Acronyms/ Abbreviations	Full meanings
MCI	Macroinvertebrate Community Index
MDS	Multidimensional Scaling
Mean	Mean value of a set of observation
Median	Median or 50 th percentile value
mg/L	milligrams per litre
Minimum	Minimum value of a set of observations
mL	Millilitre
ML	Megalitre
mm	millimetre(s)
mm ³ /L	Algal biovolume millimetre cube per litre
NATA	National Association of Testing Authorities
NHMRC	National Health and Medical Research Council
nMDS	Non-metric multidimensional scaling
No. of Obs	Number of observations
NSOOS	Northern Suburbs Ocean Outfall Sewer
NST	Northside Storage Tunnel
NSW	New South Wales
NTU	Nephelometric Turbidity unit
OECD	Organisation for Economic Cooperation and Developments
ORS	Ocean Reference Station
OSP	Ocean Sediments Program
PCA	Principal Component Analysis
PCB	Polychlorinated Biphenyls
PCO	Principal Coordinates Ordination
PCs	Principal Component axes
PERMANOVA	Permutational Analysis of Variance
PSR	Pressure-State-Response
PST	Primary sedimentation tank
R	Regression co-efficient
SCAMP	Sewer Catchment Area Management Plan
SIGNAL-SG	Stream Invertebrate Grade Number Average Level - Genus taxonomic level for the greater Sydney region. Which is a biotic index based on freshwater macroinvertebrate diversity, abundance and tolerance to organic pollution
SIMPER	Similarity percentage
SOV	System overflow volume
SRA	State Recreation Area
Stats	Statistics
Std dev	Standard deviation
STSIMP	Sewage Treatment System Impact Monitoring Program




Acronyms/ Abbreviations	Full meanings
SWOOS	Southern and Western Suburbs Ocean Outfall Sewer
TOC	Total organic carbon
USEPA	United States Environmental Protection Agency
WET	Whole Effluent Toxicity
WWTP	Wastewater treatment plant
WRP	Water Recycling Plant
µg/L	micrograms per litre
µS/cm	micro Siemens per centimetre (unit of conductivity)

Appendix B : List of rainfall stations and location details

Table B-1 Rainfall stations used for categorising wastewater data as dry or wet weather days

Catchments	Rainfall station (Hydstra code and site name/ description)	Latitude	Longitude	WWTP
Upper Nepean	568053 Picton WWTP	-34.2029	150.6148	Picton and West Camden WWTPs
	568130 West Camden WWTP (composite)	-34.0590	150.6809	
Mid Nepean	567163 Regent Ville Rural Fire Service	-33.7745	150.6716	Penrith, St Marys, Glenbrook*, Warragamba* and Wallacia WWTPs
	567087 St Marys WWTP	-33.7342	150.7692	
	568044 Warragamba Water Filtration Plant	-33.8915	150.5983	
Lower Nepean	567084 Quakers Hill WWTP	-33.7365	150.8783	Quakers Hill, Richmond, North Richmond, Winmalee and Riverstone WWTPs
	567085 Richmond WWTP	-33.6080	150.7671	
	563069 North Richmond WWTP	-33.5748	150.7156	
	563146 Winmalee WWTP	-33.6767	150.6250	
	567100 Riverstone WWTP	-33.6562	150.8477	
Lower Hawkesbury	567076 Castle Hill WWTP	-33.7111	150.9842	Castle Hill and Rouse Hill WWTPs
	567102 Dural (WPS14)	-33.6969	151.0277	
Berowra	567120 Brooklyn WWTP	-33.5513	151.1959	Brooklyn, West Hornsby and Hornsby Heights WWTPs
	566055 Hornsby Bowling Club*	-33.7067	151.1070	
	566073 Pymble Bowling Club	-33.7408	151.1394	
	566053 Hornsby Heights WWTP	-33.6672	151.1047	
South West Sydney	567077 Fairfield WWTP	-33.8807	150.9504	Fairfield, Glenfield and Liverpool WWTPs
	567078 Glenfield WWTP	-33.9827	150.9071	
	566049 Liverpool WWTP	-33.9218	150.9386	




Catchments	Rainfall station (Hydstra code and site name/ description)	Latitude	Longitude	WWTP
Cronulla	566078 South Cronulla	-34.0700	151.1517	Cronulla WWTP
	566018 Cronulla WWTP	-34.0307	151.1635	
Illawarra	568162 Balgownie Reservoir	-34.3928	150.8703	Bellambi, Port Kembla, Shellharbour, Wollongong and Bombo WWTPs
	568173 Berkeley (Berkeley Sports and Social Club)	-34.4830	150.8473	
	568171 Albion Park Bowling Club	-34.5703	150.7684	
	568181 Figtree Bowling Club	-34.4363	150.8646	
	568188 Kiama Water Tank	-34.6735	150.8434	
North Sydney Coast	566089 Manly Croquet Club (formerly Manly Golf Course)*	-33.7906	151.2758	North Head and Warriewood WWTPs
	566100 North Head WWTP	-33.8080	151.3019	
	566051 Warriewood WWTP (Composite)	-33.6912	151.2993	
Malabar	566026 Marrickville Bowling Club	-33.9099	151.1641	Malabar WWTP
	567077 Fairfield WWTP	-33.8807	150.9504	
	567078 Glenfield WWTP	-33.9827	150.9071	
	566049 Liverpool WWTP	-33.9218	150.9386	
Bondi	566032 Paddington (Composite)	-33.8870	151.2253	Bondi WWTP
	566038 Vaucluse Bowling club	-33.8578	151.2788	

*Not monitored after 2016

Table B-2 Rainfall stations used for categorising receiving water quality data as dry or wet weather days

Catchments	Rainfall station (Hydstra code and site name/ description)	Latitude	Longitude	Water quality monitoring Sites
Upper Nepean	568053 Picton WWTP	-34.2029	150.6148	N92, N75 and N67
	568130 West Camden WWTP (composite)	-34.0590	150.6809	
	568044 Warragamba Water Filtration Plant	-33.8915	150.5983	
Mid Nepean	567163 Regentville Rural Fire Service	-33.7745	150.6716	N57 and N51
	567087 St Marys WWTP	-33.7342	150.7692	
Lower Nepean	567084 Quakers Hill WWTP	-33.7365	150.8783	N48A, N44, N39, N35 and NS04A
	567085 Richmond WWTP	-33.6080	150.7671	
	563069 North Richmond WWTP	-33.5748	150.7156	
	563146 Winmalee WWTP	-33.6767	150.6250	
	567100 Riverstone WWTP	-33.6562	150.8477	
Lower Hawkesbury	567076 Castle Hill WWTP	-33.7111	150.9842	N3001, N26, N18, N2202 and NC11A
	567102 Dural (WPS14)	-33.6969	151.0277	
Berowra	566055 Hornsby Bowling Club*	-33.7067	151.1070	NB13 and NB11
	566073 Pymble Bowling Club	-33.7408	151.1394	
	566053 Hornsby Heights WWTP	-33.6672	151.1047	
Port Jackson Lower	566087 Gladesville Bowling Club	-33.8226	151.1294	PJLC and PJTB
	566073 Pymble Bowling Club	-33.7408	151.1394	
Port Jackson Upper	566087 Gladesville Bowling Club	-33.8226	151.1294	PJ015, PJPRA, PJCB2 and PJDFP
	566082 Auburn RSL Bowling Club	-33.8602	151.0190	
	566032 Paddington (composite)	-33.8870	151.2253	
Middle Harbour	566089 Manly Croquet Club (formerly Manly Golf Course)*	-33.7906	151.2758	PJDR, PJSB and PJCB1
	566100 North Head WWTP	-33.8080	151.3019	




Catchments	Rainfall station (Hydstra code and site name/ description)	Latitude	Longitude	Water quality monitoring Sites
	566051 Warriewood WWTP (composite)	-33.6912	151.2993	
Georges River Lower	566026 Marrickville Bowling Club	-33.9099	151.1641	GR01, CR04A, GRRB and GRFB
	566020 Enfield (composite site)	-33.9005	151.0879	
	566028 Eastlakes Sydney Water Depot	-33.9256	151.2203	
Georges River Upper	567077 Fairfield WWTP	-33.8807	150.9504	GR19, GR22 and GROB
	567078 Glenfield WWTP	-33.9827	150.9071	
	566049 Liverpool WWTP	-33.9218	150.9386	
Port Hacking	566078 South Cronulla Bowling Club	-34.0700	151.1517	PHLPB, WL83
	566018 Cronulla WWTP	-34.0307	151.1635	
Lagoons	566051 Warriewood WWTP (composite)	-33.6912	151.2993	Lagoon sites (CC-sites, DW-sites, ML sites and NL_sites)
	566100 North Head WWTP	-33.8080	151.3019	
	566089 Manly Croquet Club (formerly Manly Golf Course)*	-33.7906	151.2758	

*Not monitored after 2016



Figure B-1 Rainfall stations used for categorising wastewater data as dry or wet weather days



Figure B-2 Rainfall stations used for categorising receiving water quality data as dry or wet weather days



Appendix C : Trends in discharge and reuse volumes, discharge quality and pollutant loads from coastal WWTPs

The coastal WWTPs are presented in the following order from North coast to South coast:

- Warriewood WWTP
- North Head WWTP
- Bondi WWTP
- Malabar WWTP
- Cronulla WWTP
- Wollongong WWTP
- Shellharbour WWTP
- Bombo WWTP

- Malabar storm WWTPs (Fairfield, Glenfield and Liverpool WWTPs) discharging to inland waters in wet weather only

Tests conducted on wastewater are specified under the Environment Protection Licences (EPL) issued by the NSW EPA for each WWTP. All measured analytes that have EPL concentration and load limits are presented in this Appendix.

Under each WWTP, trend plots are presented on:

- Discharge and reuse volume
- Discharge quality
- Discharge loads

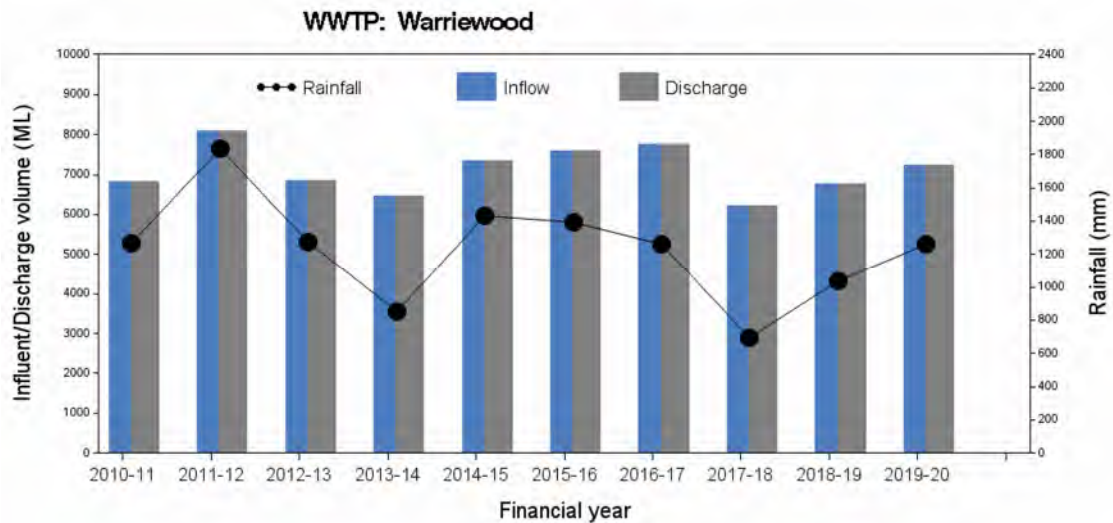
Discharge quality and load plots are included in following sub-groups and then analytes presented in alphabetical order:

- Nutrients
- Major conventional analytes
- Toxicity
- Trace metals
- Other chemicals and organics (including pesticides)

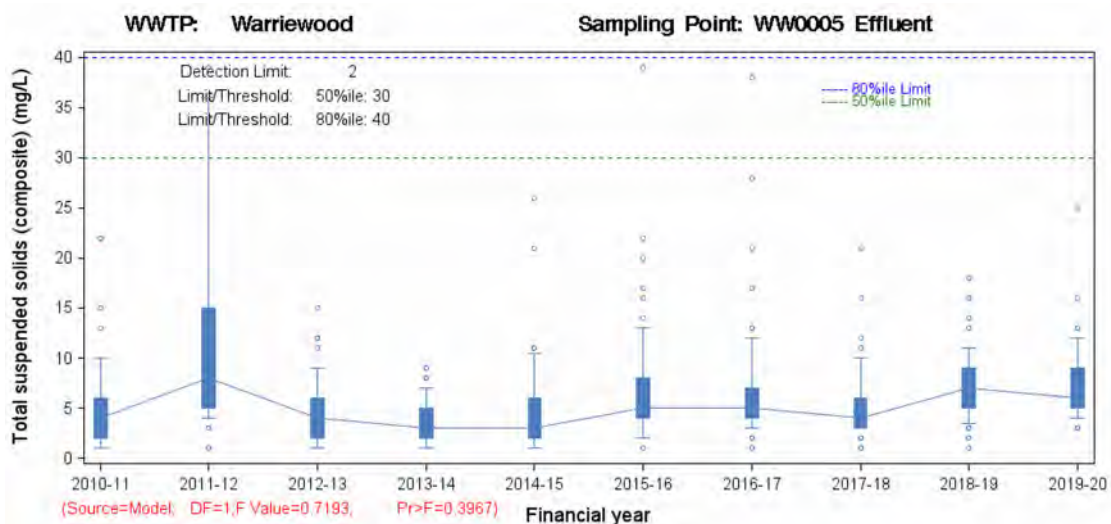
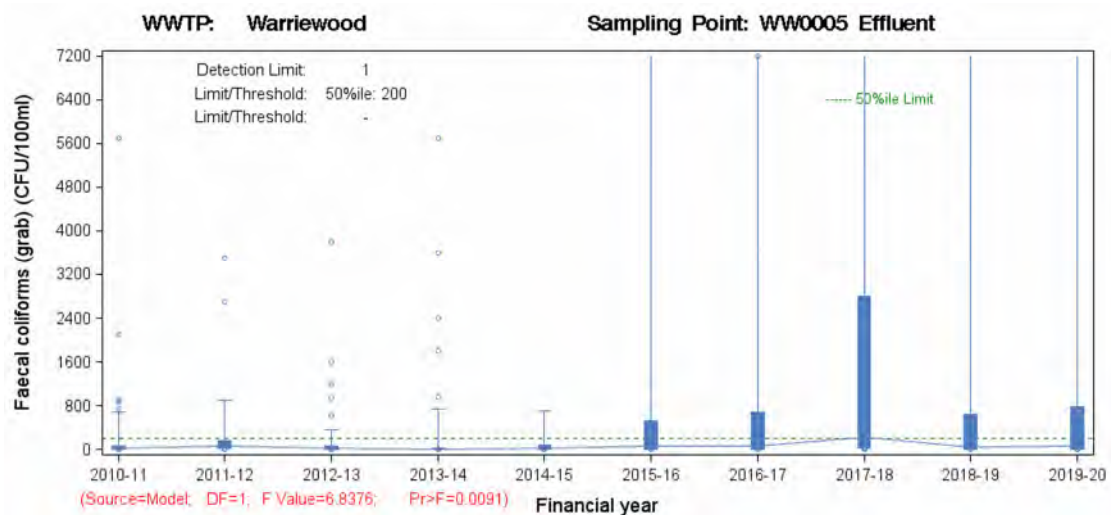
Where an analyte shows a trend (positive or negative) two plots are presented (where required) - one with the licence limits and one zoomed in to provide a clearer view of the trend.

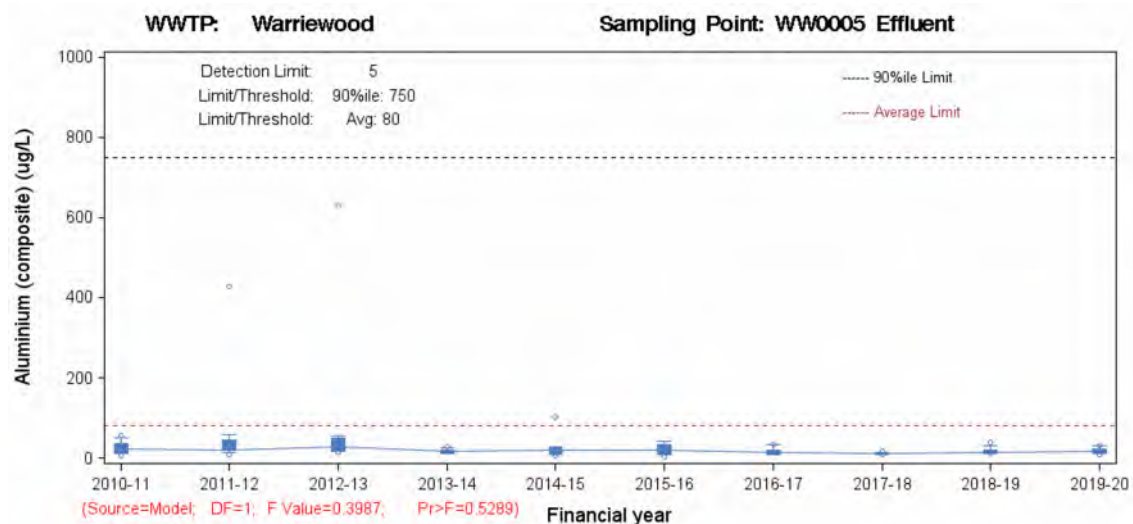
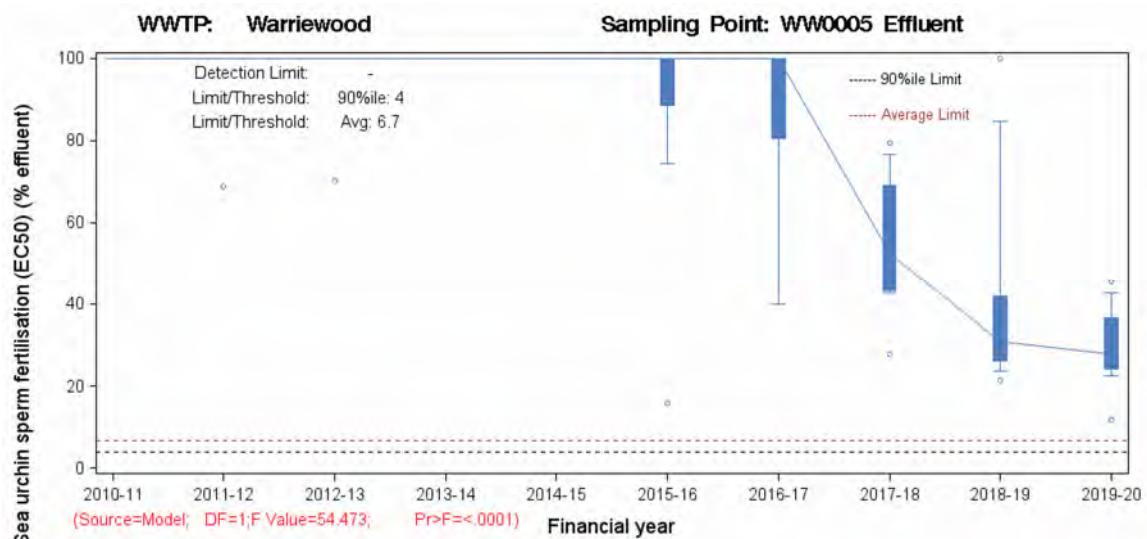
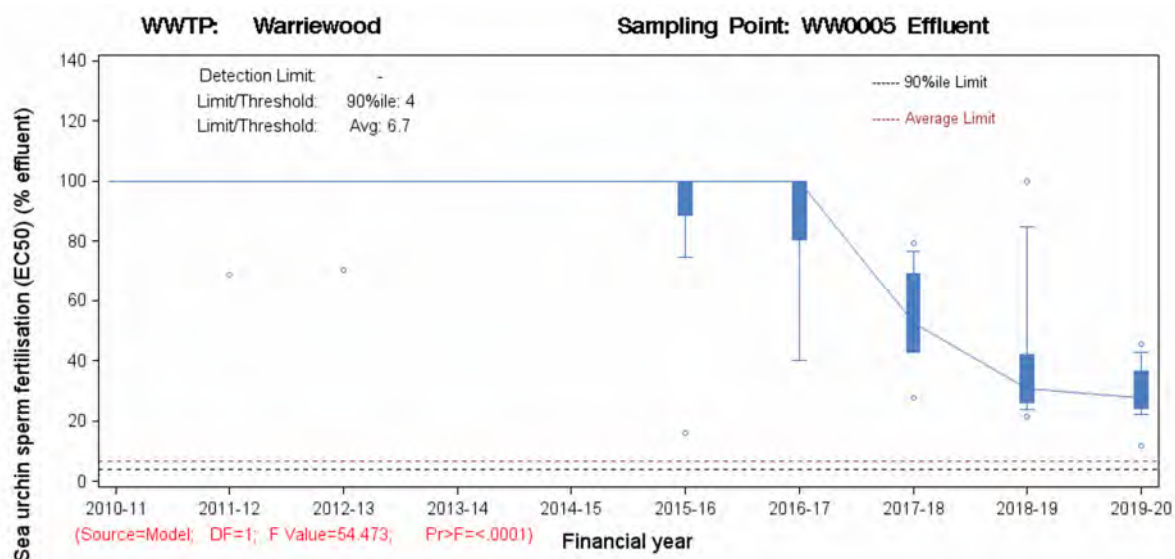
Warriewood WWTP

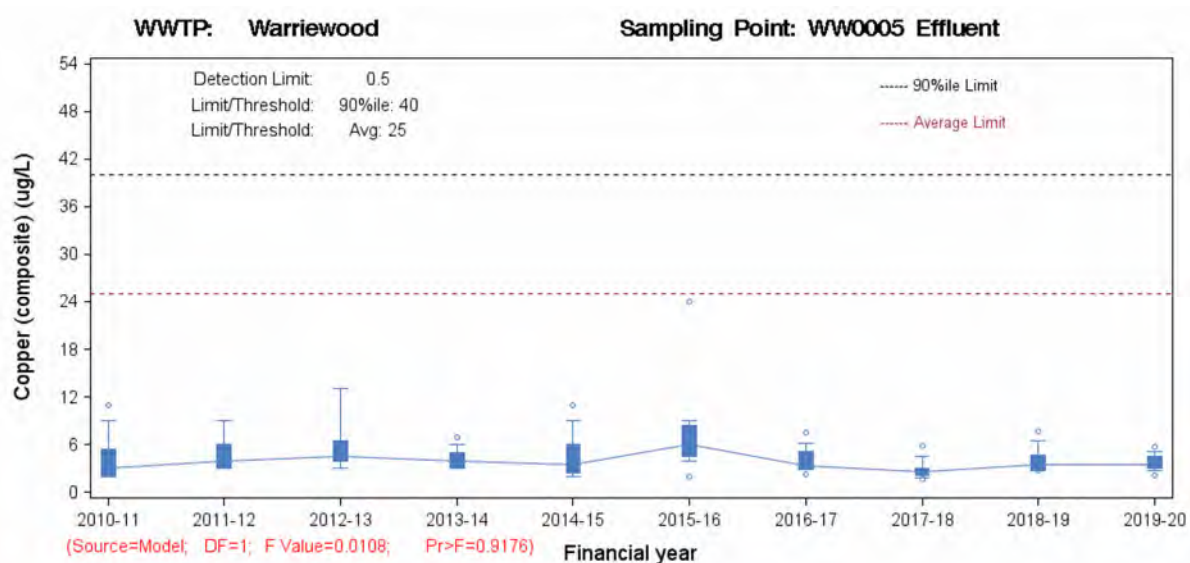
Discharge volume and rainfall



Discharge quality: Major conventional analytes

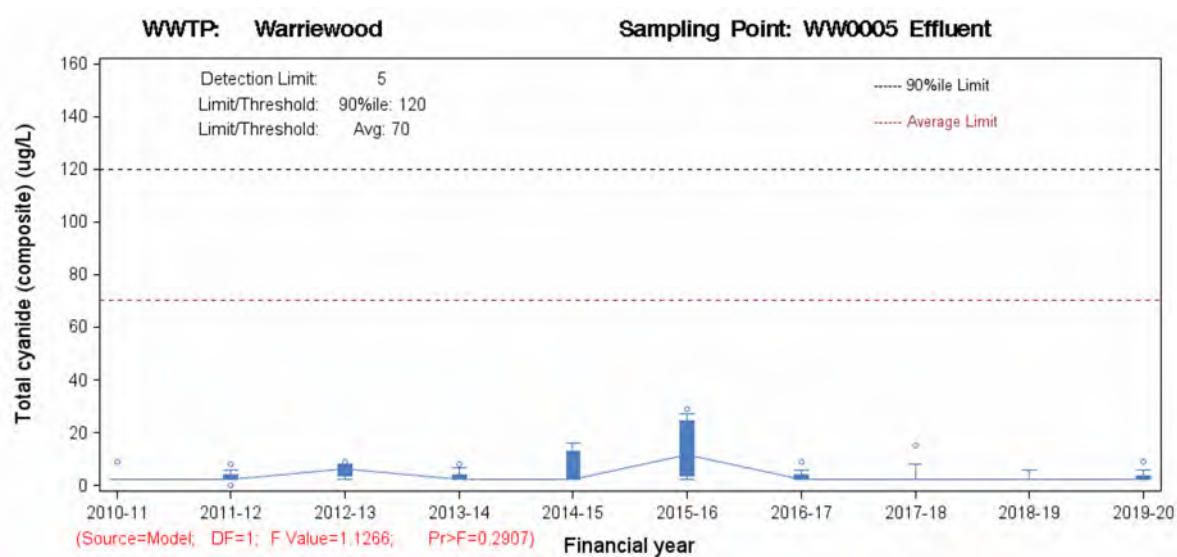


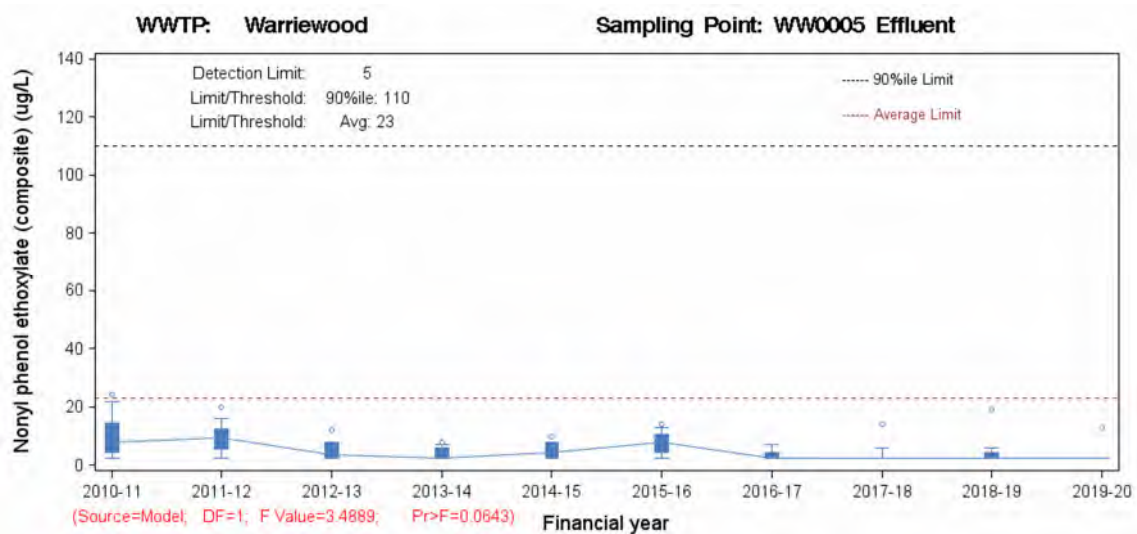




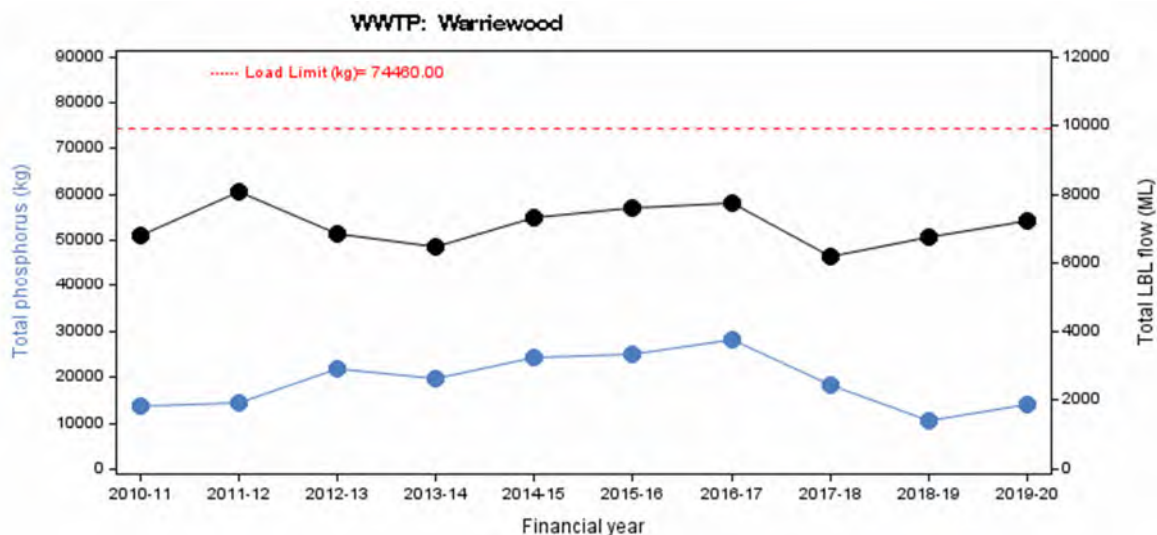
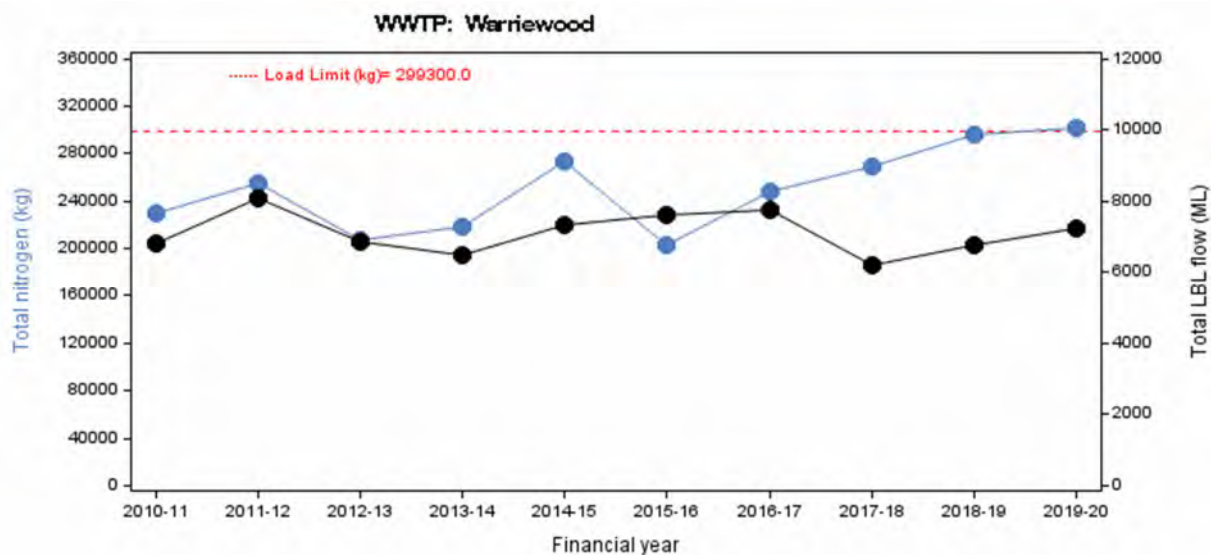
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

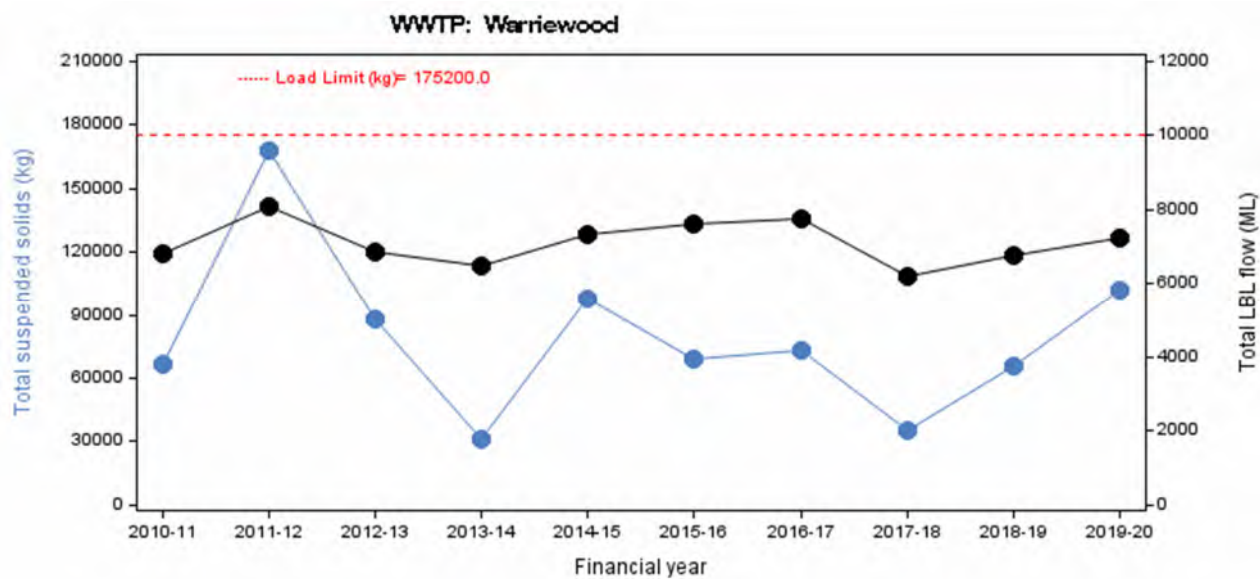
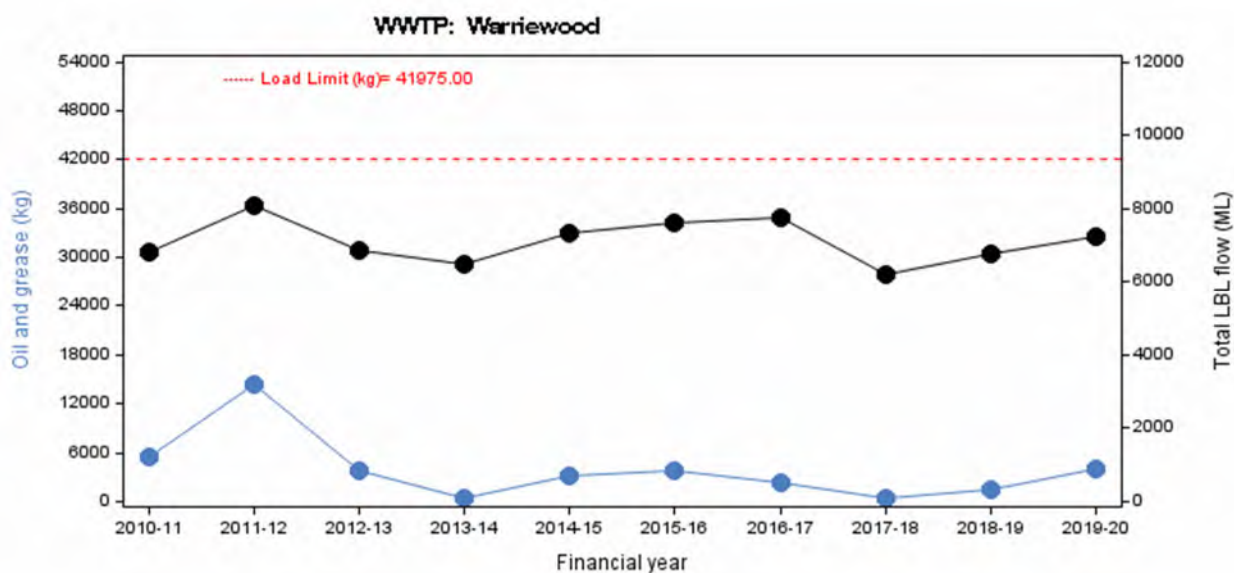
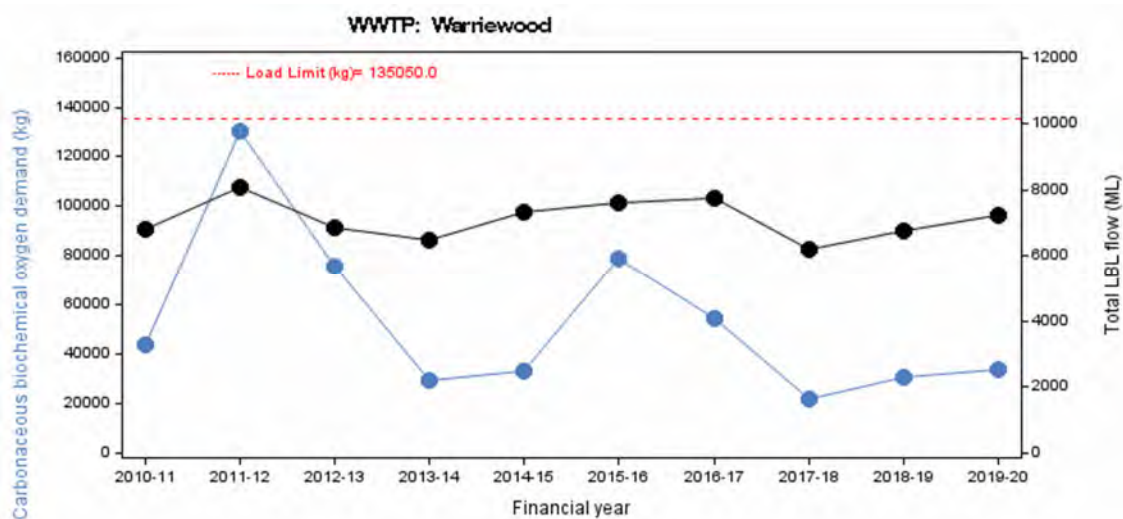
Discharge quality: Other chemicals and organics (including pesticides)





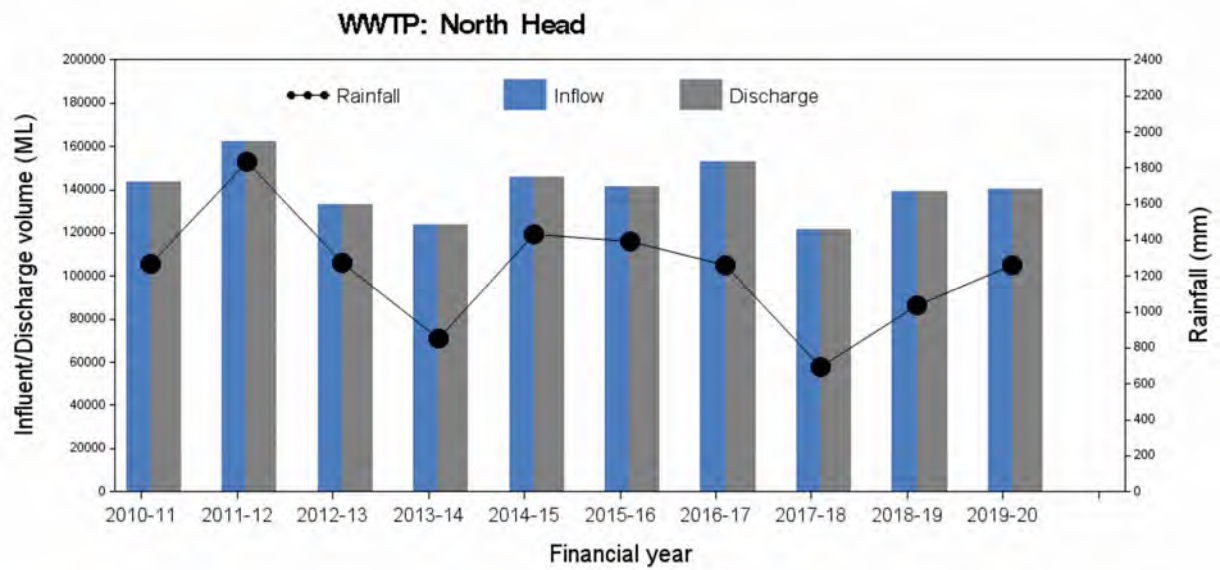
Discharge load: Nutrients



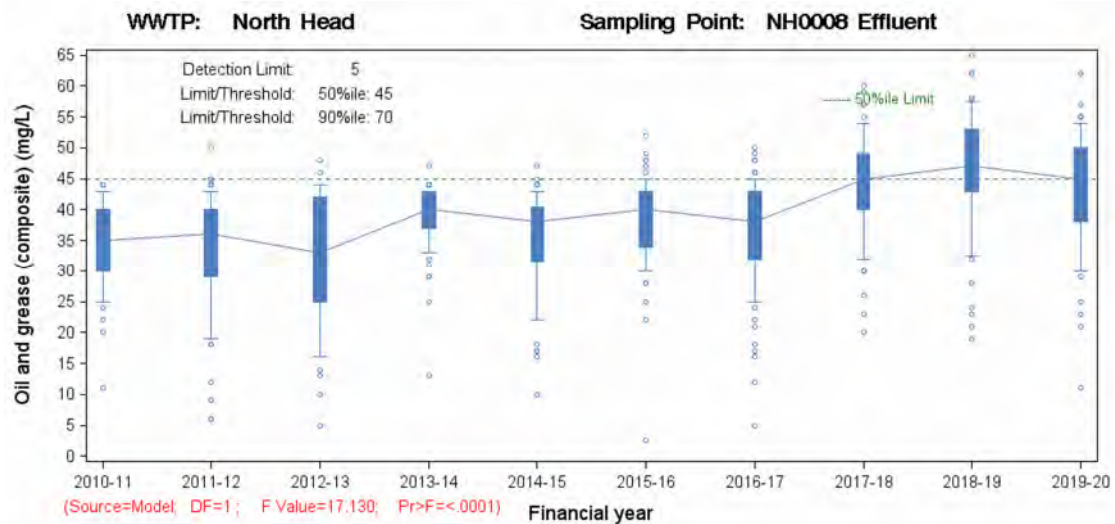
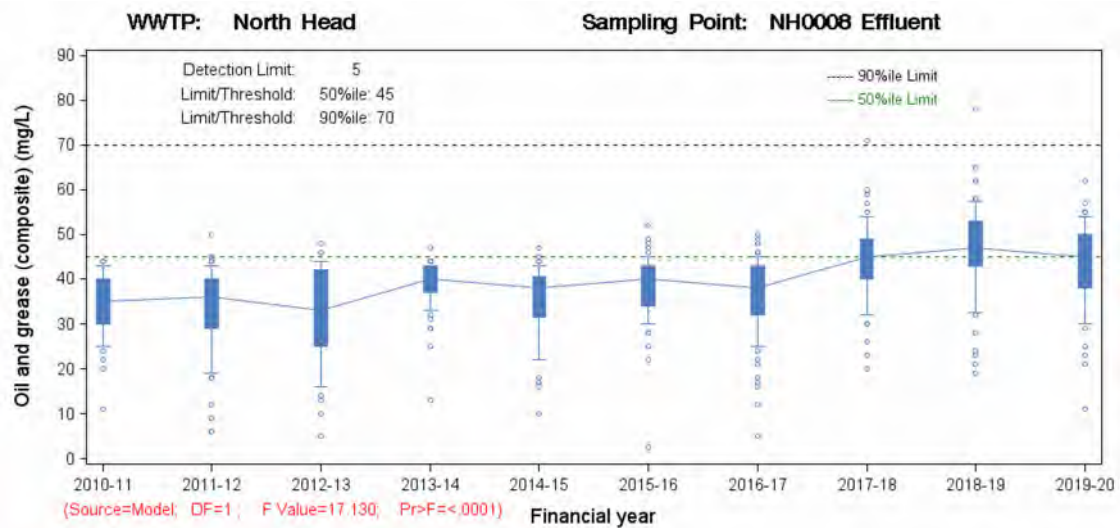


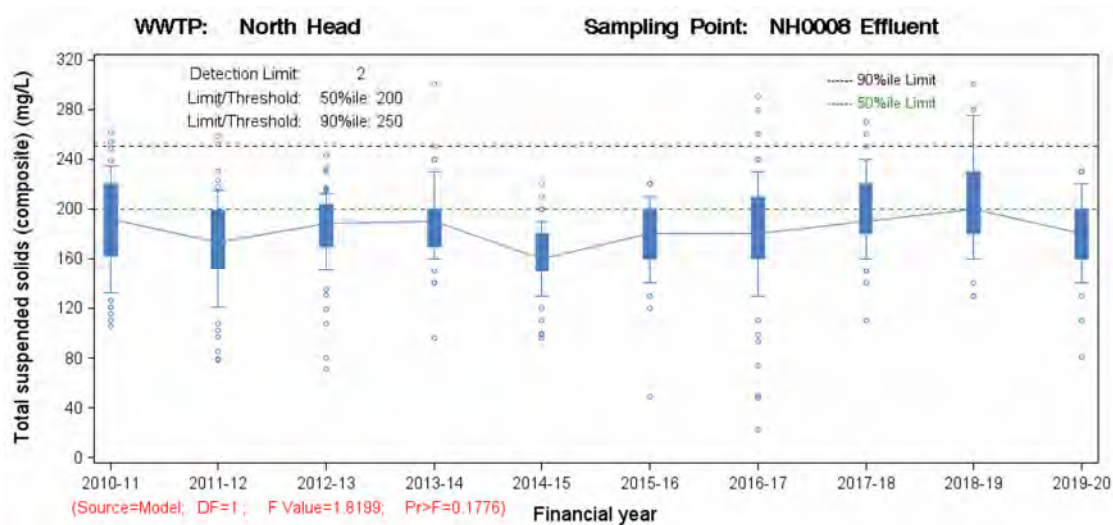
North Head WWTP

Discharge volume and rainfall

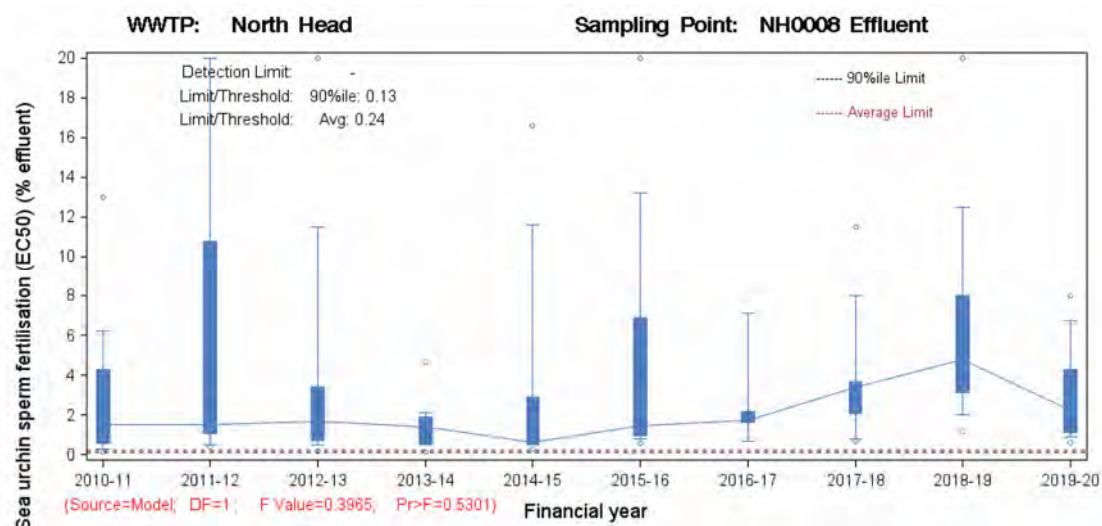


Discharge quality: Major conventional analytes

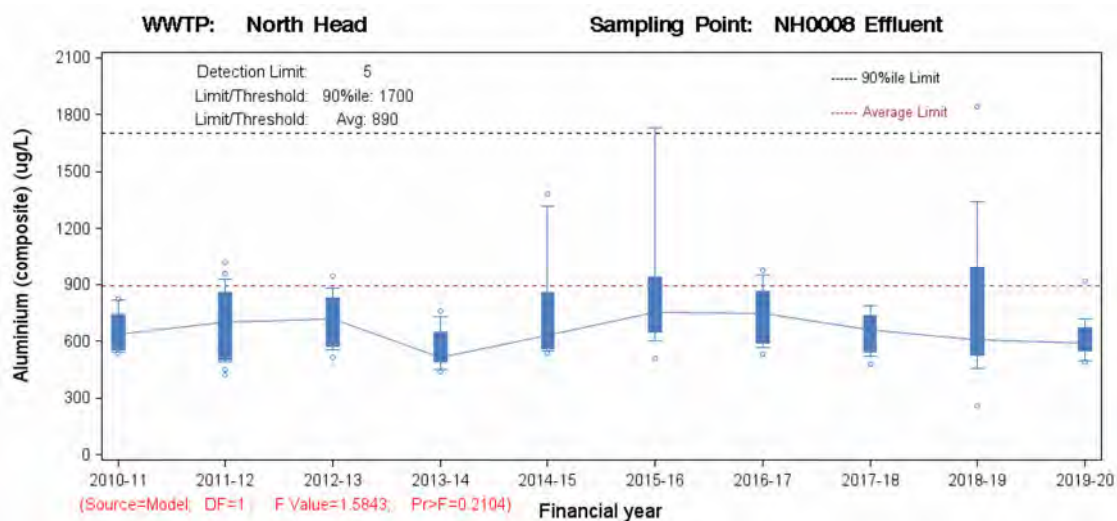


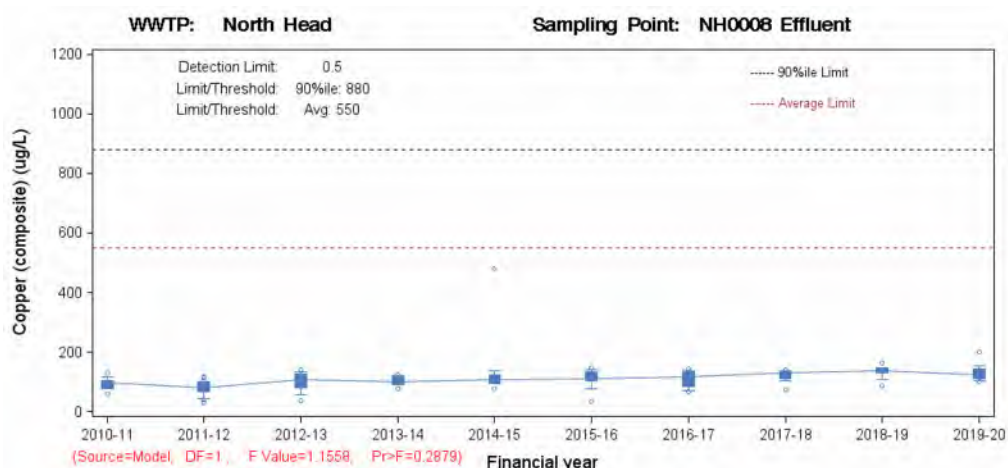


Discharge quality: Toxicity



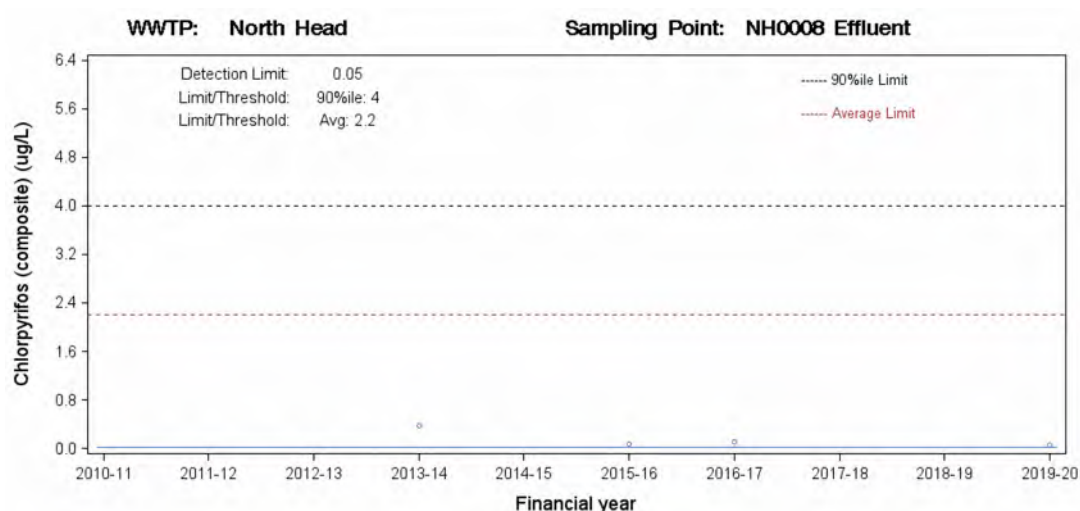
Discharge quality: Trace metals



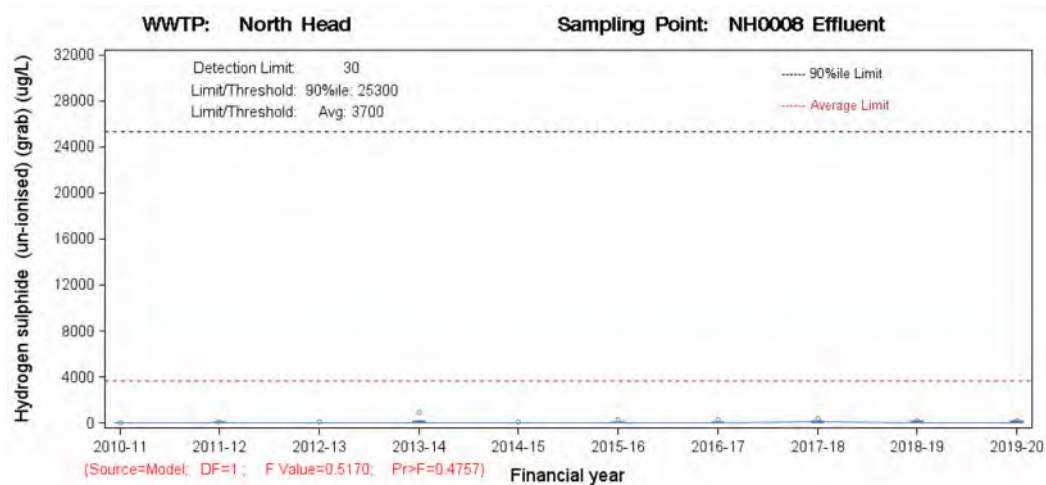


Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

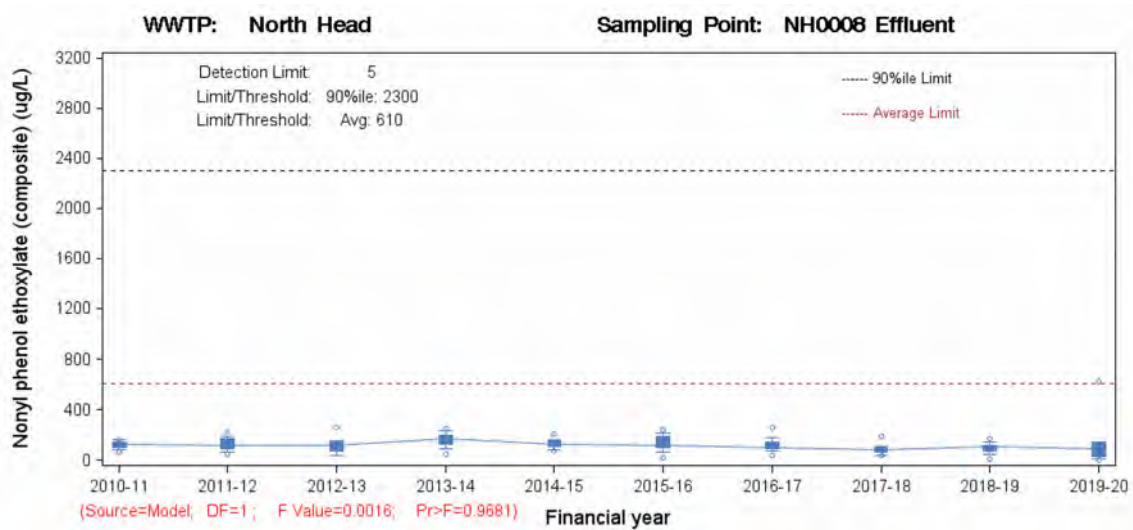
Discharge quality: Other chemicals and organics (including pesticides)



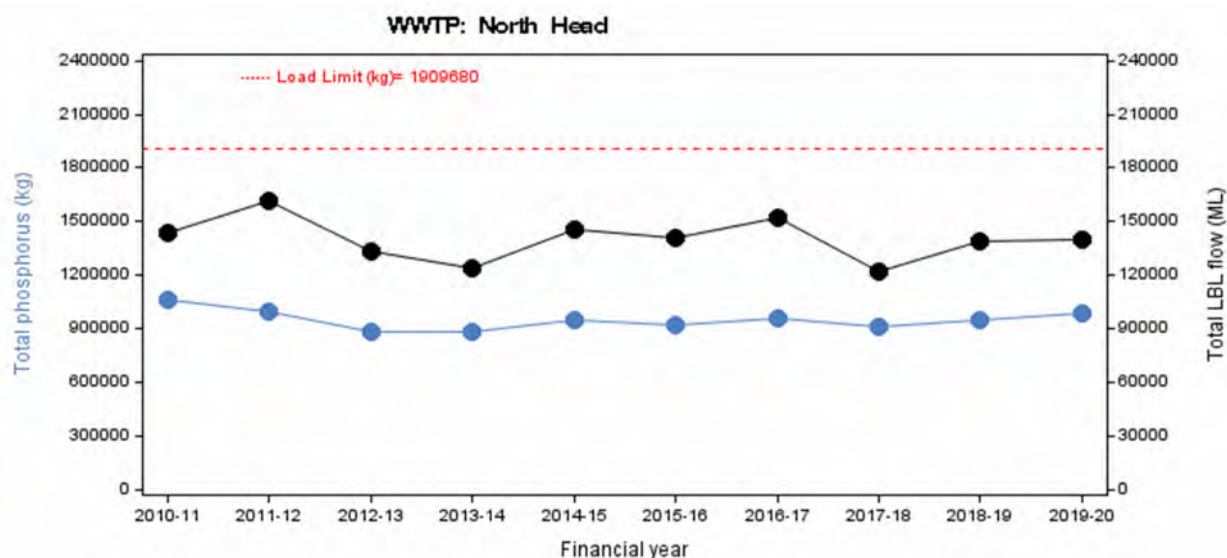
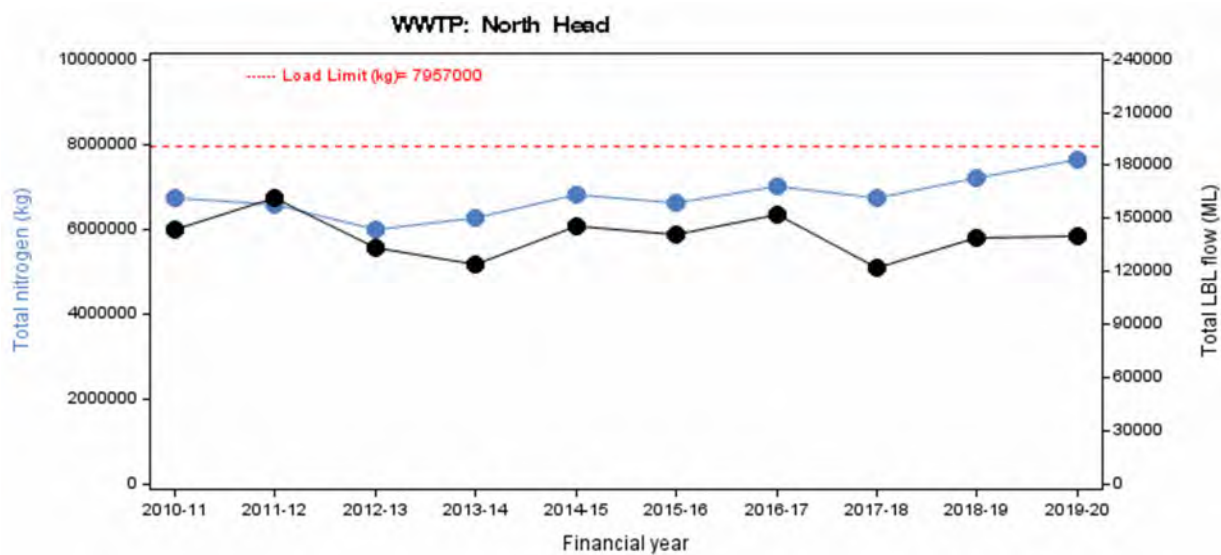
Note: Statistical test was not conducted because >90% of results were below the detection limit.

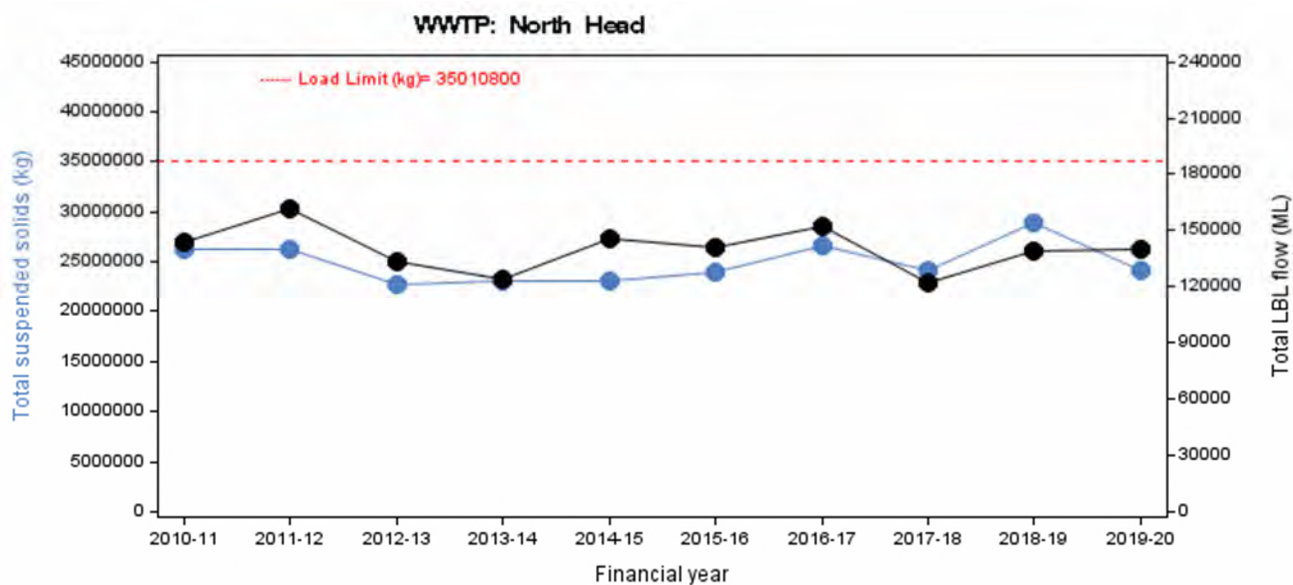
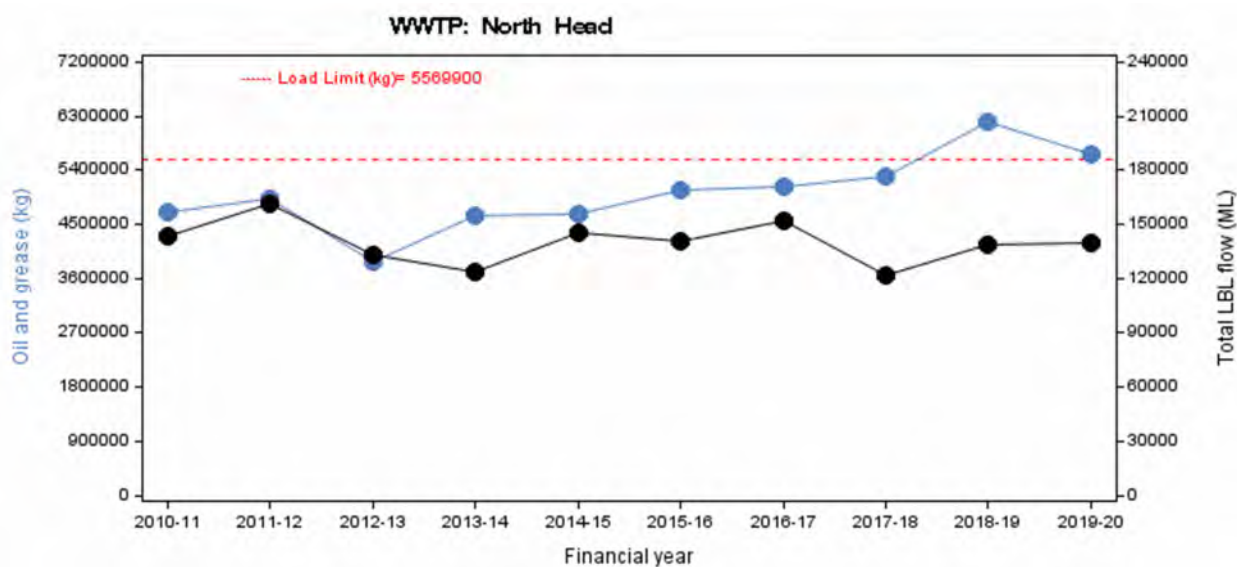
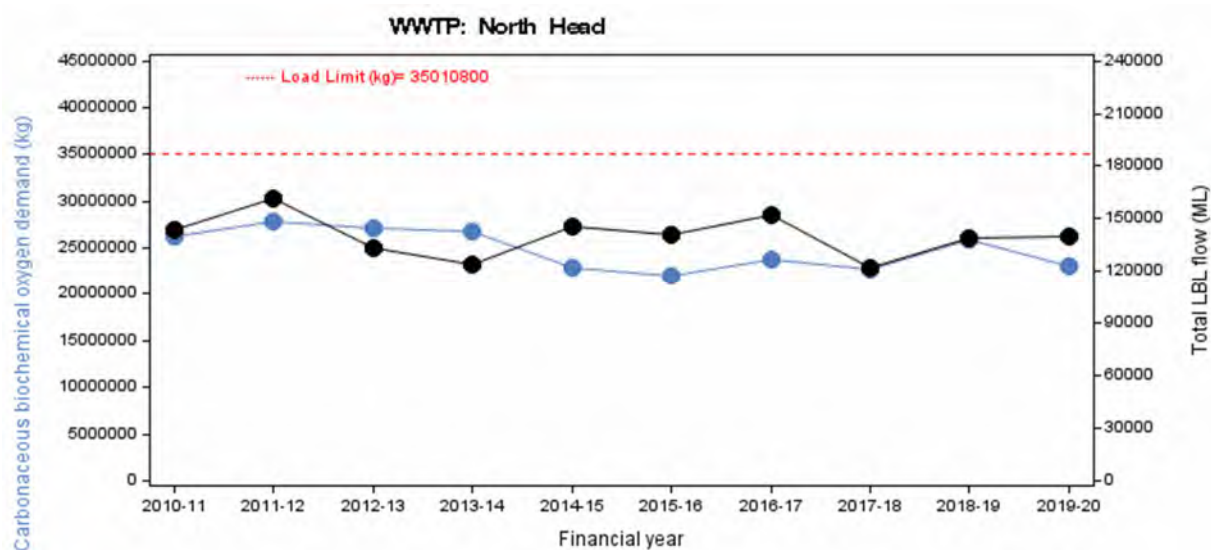


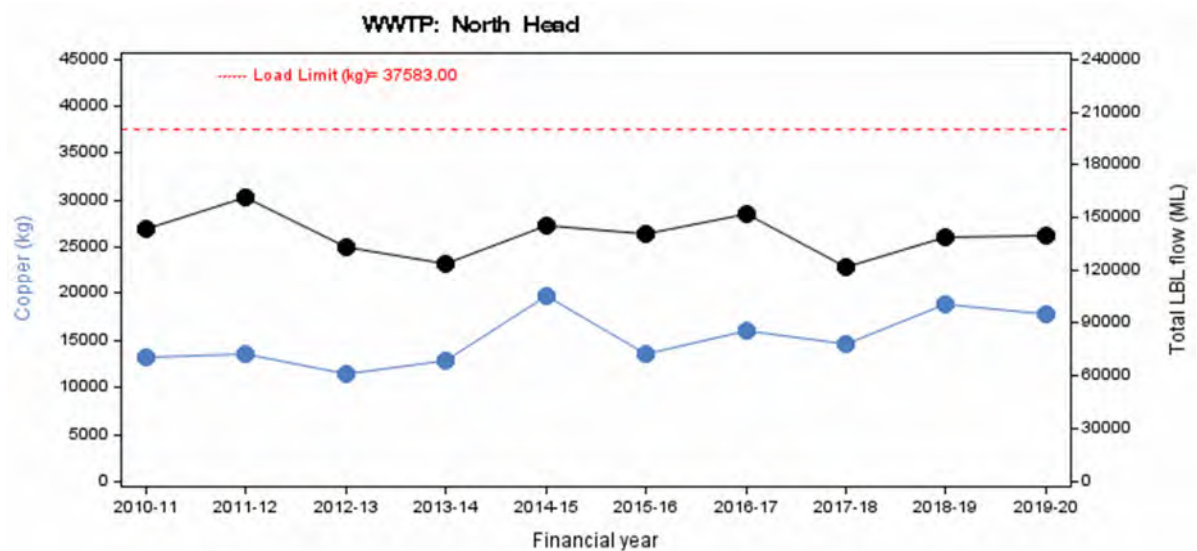
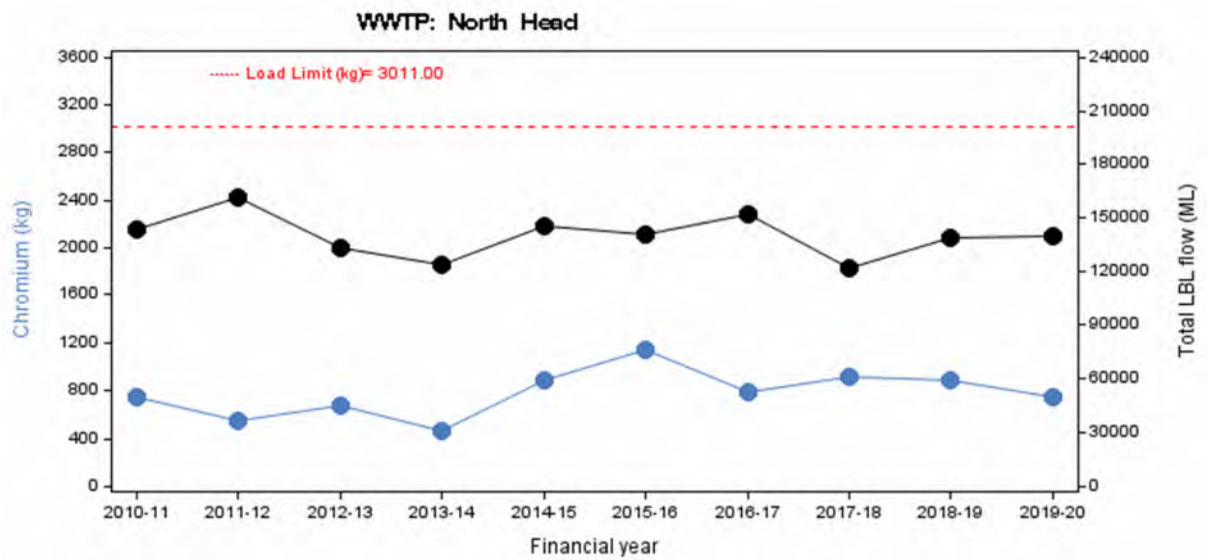
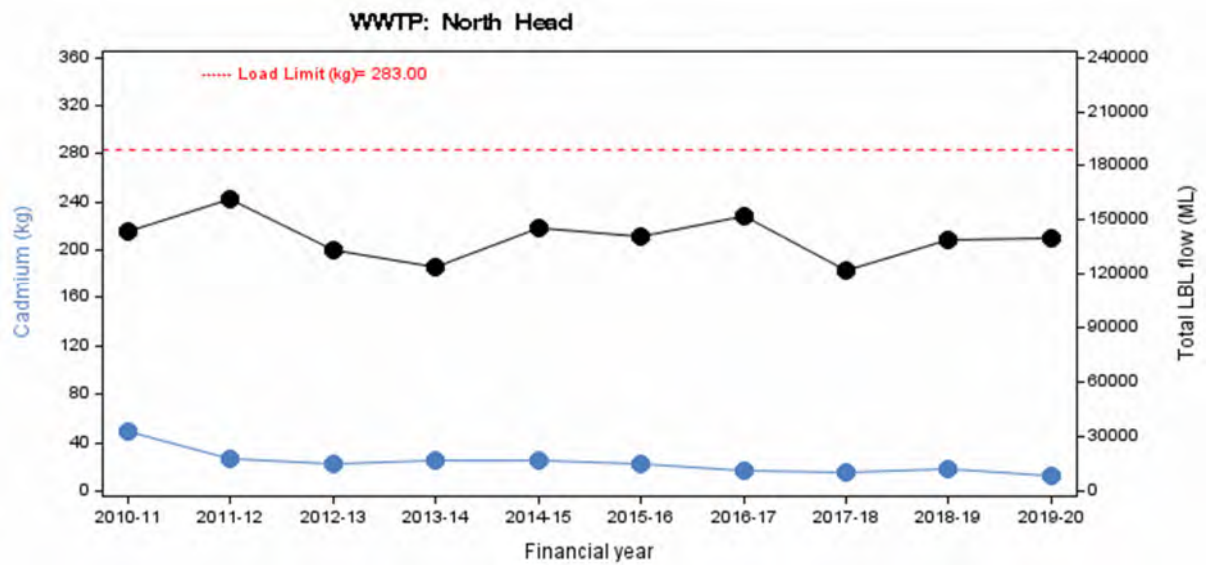
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

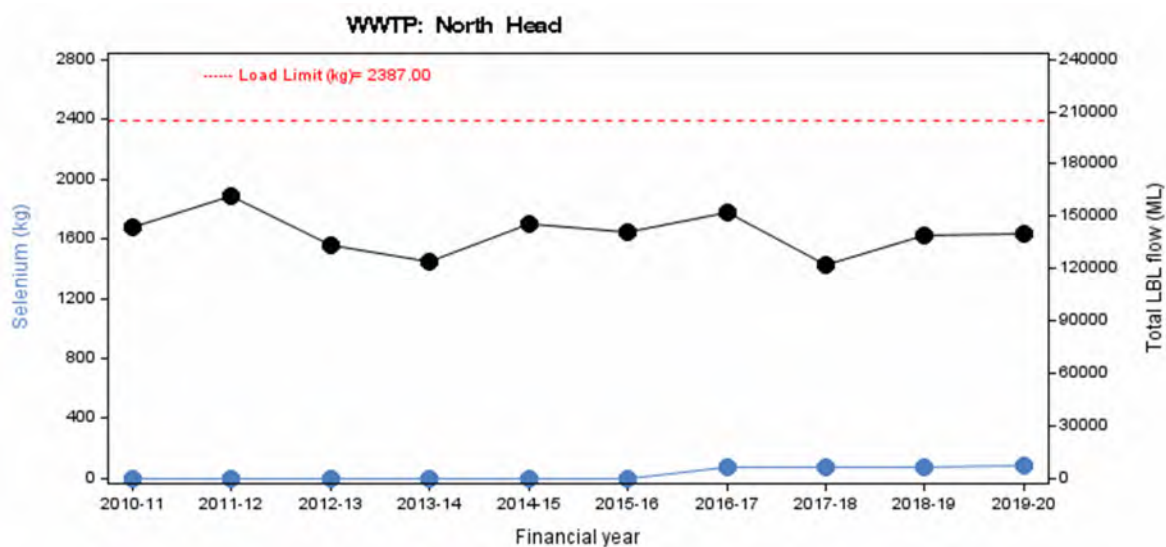
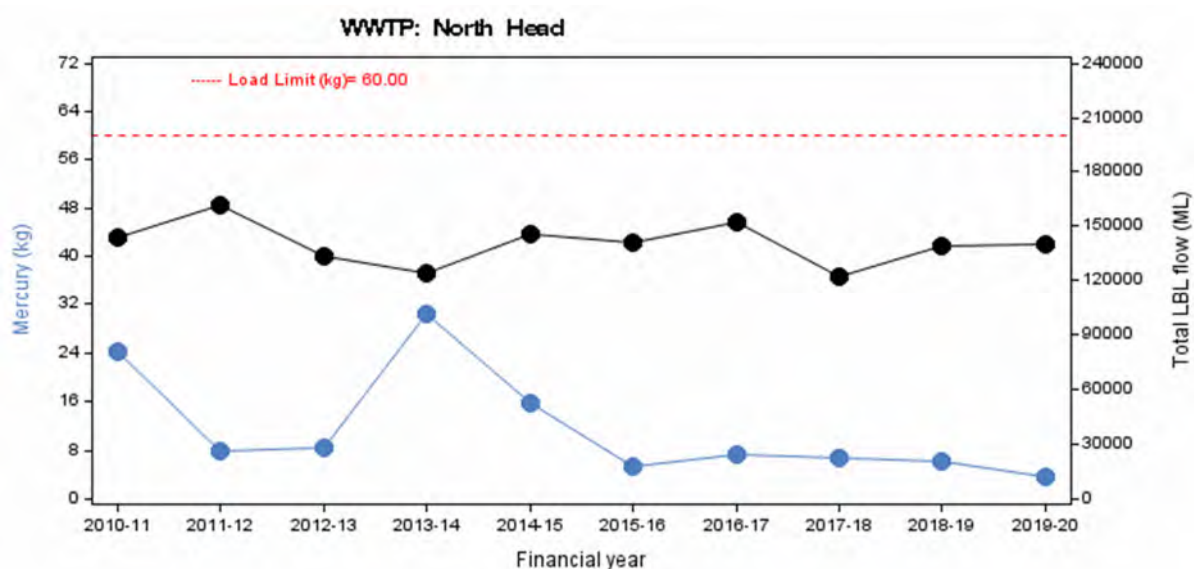
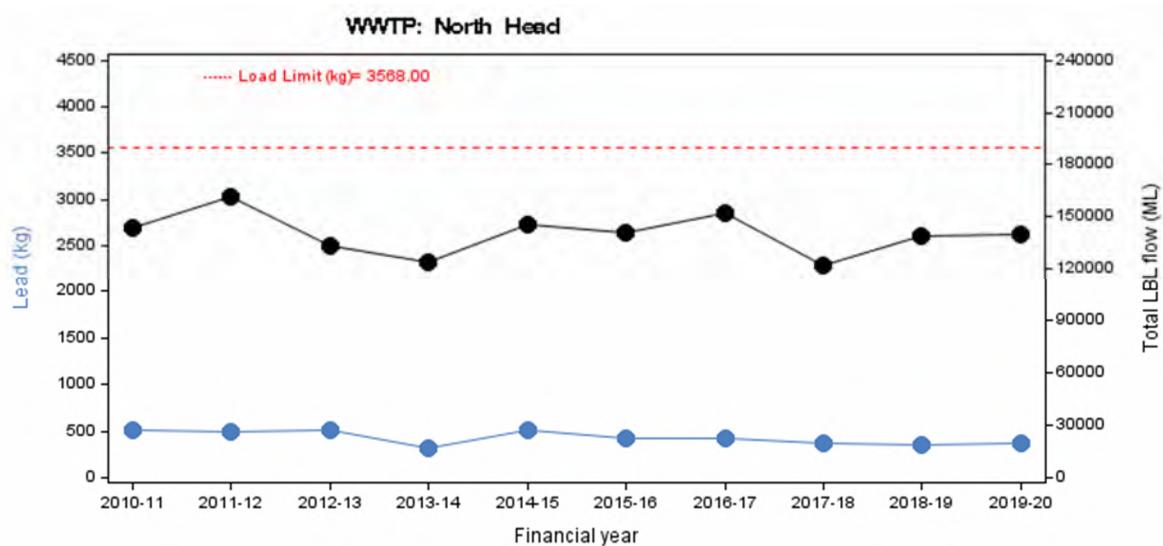


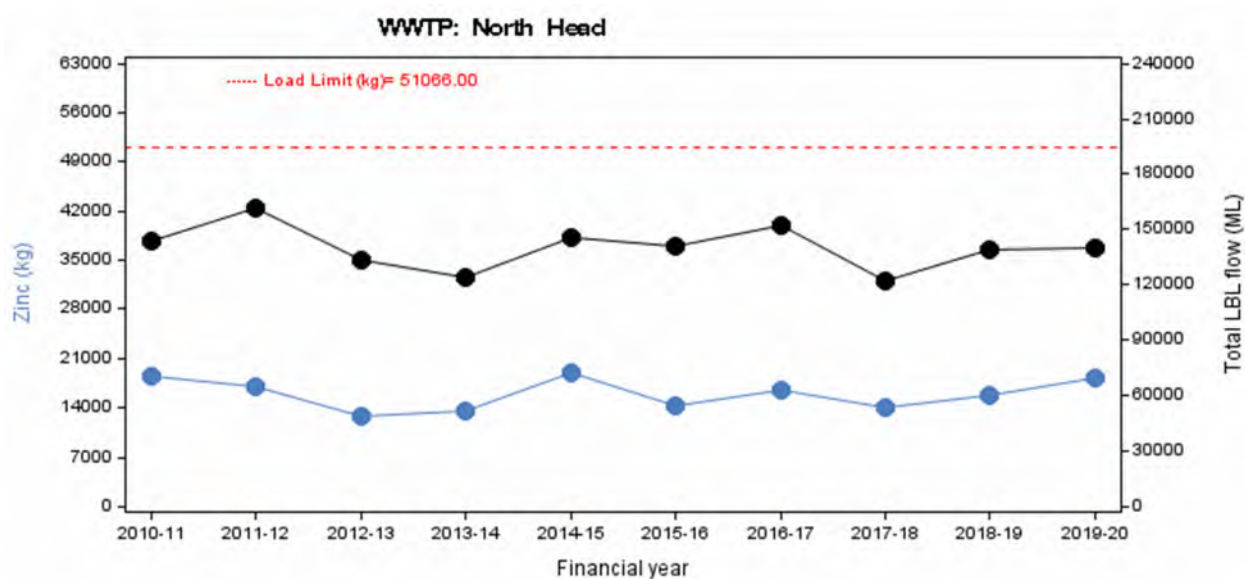
Discharge load: Nutrients



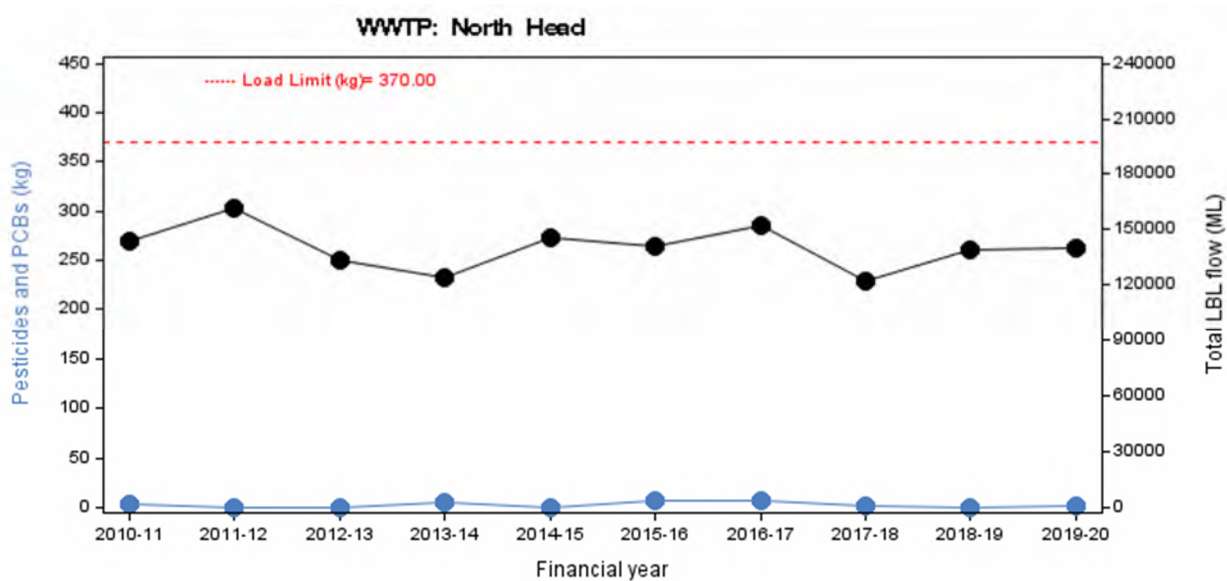






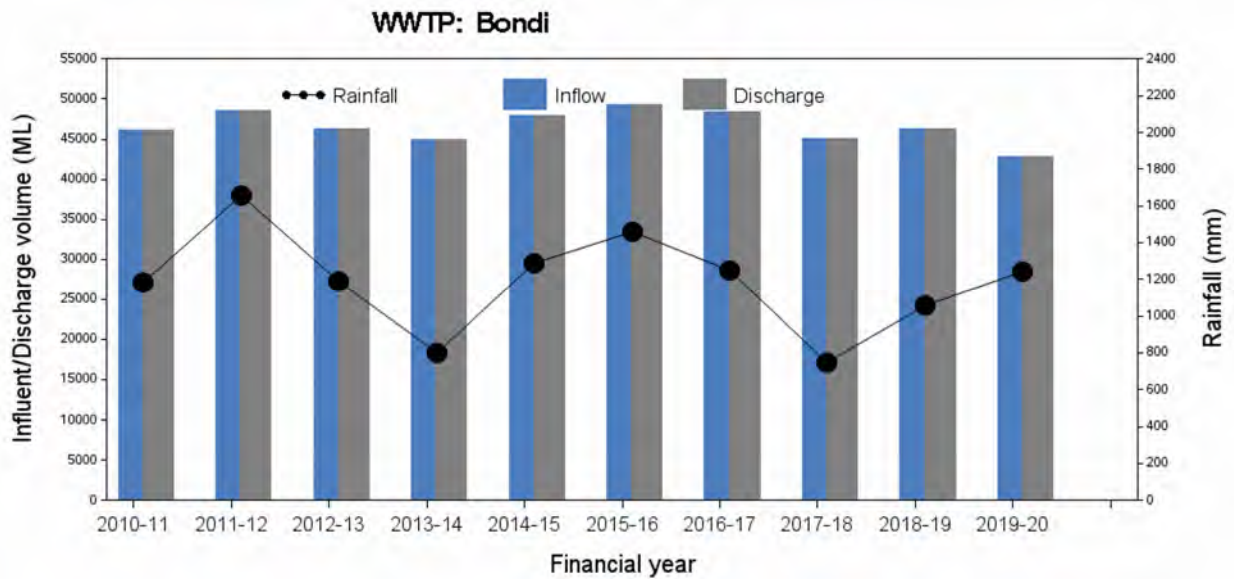


Discharge load: Other chemicals and organics (including pesticides)

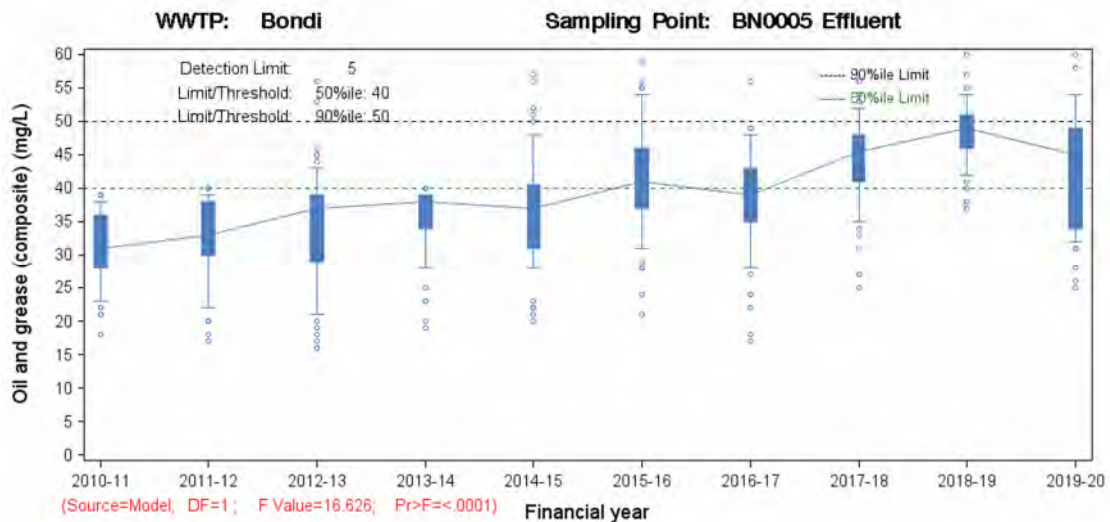
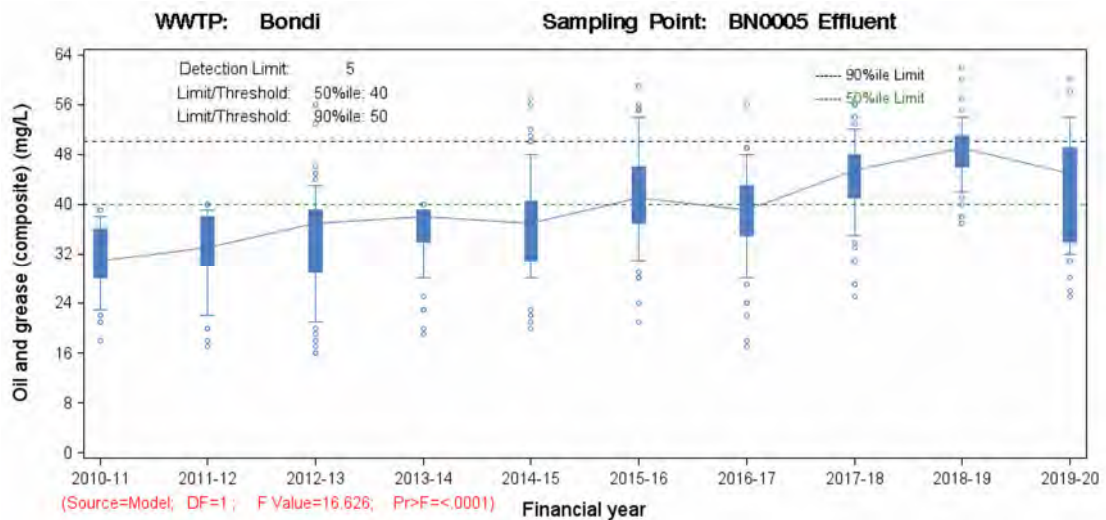


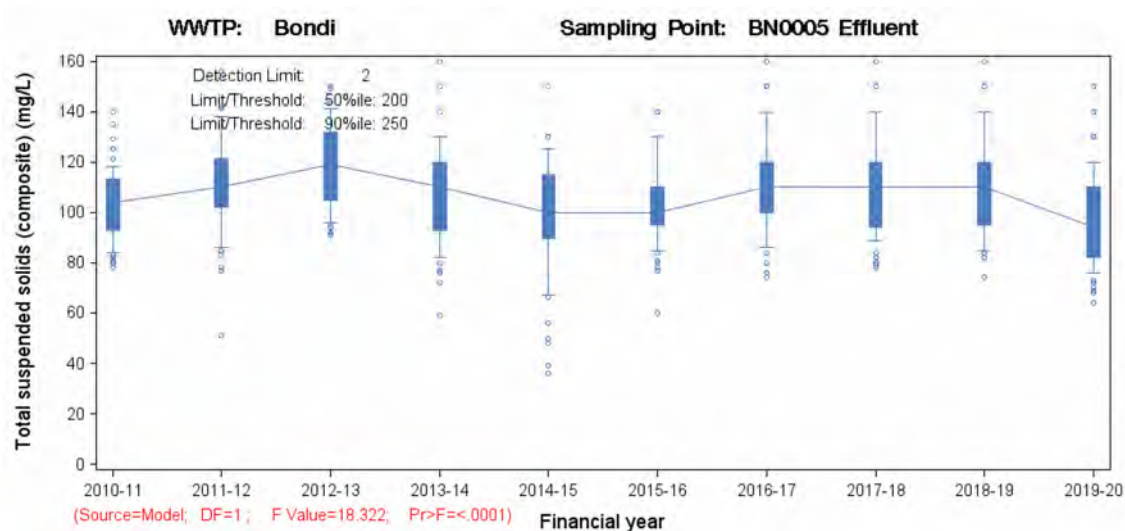
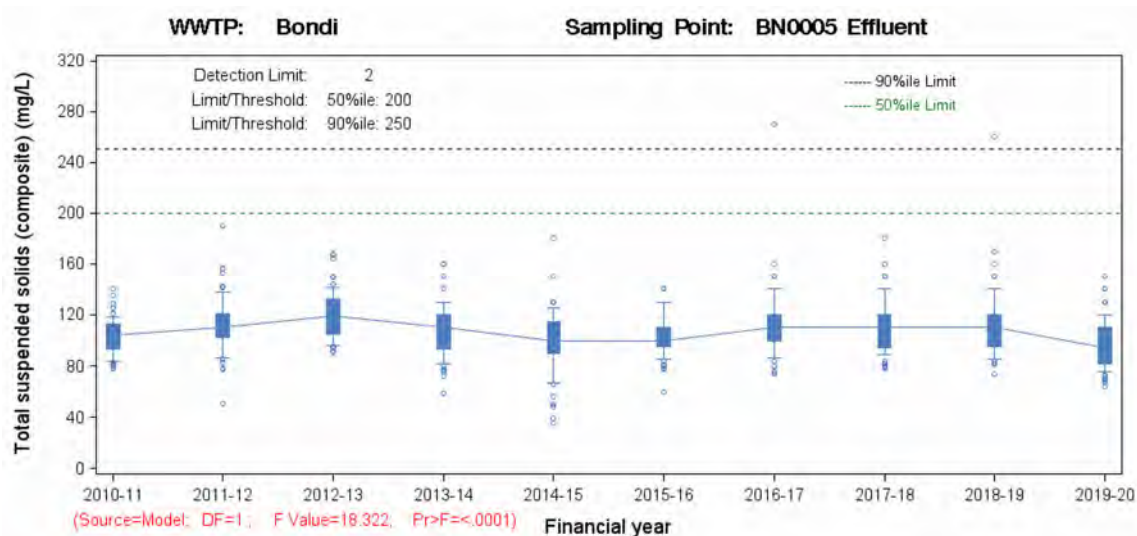
Bondi WWTP

Discharge volume and rainfall

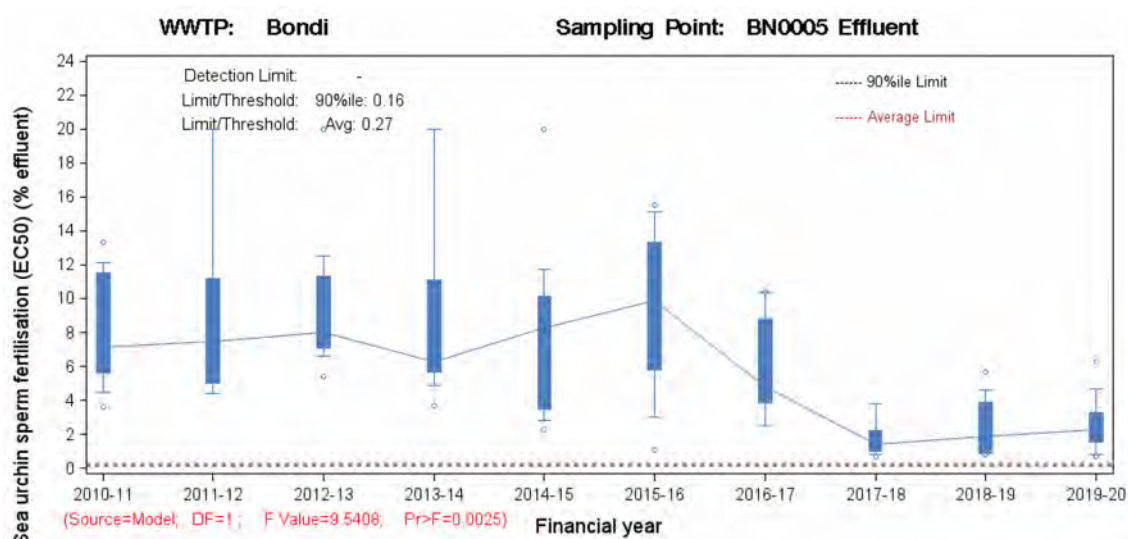


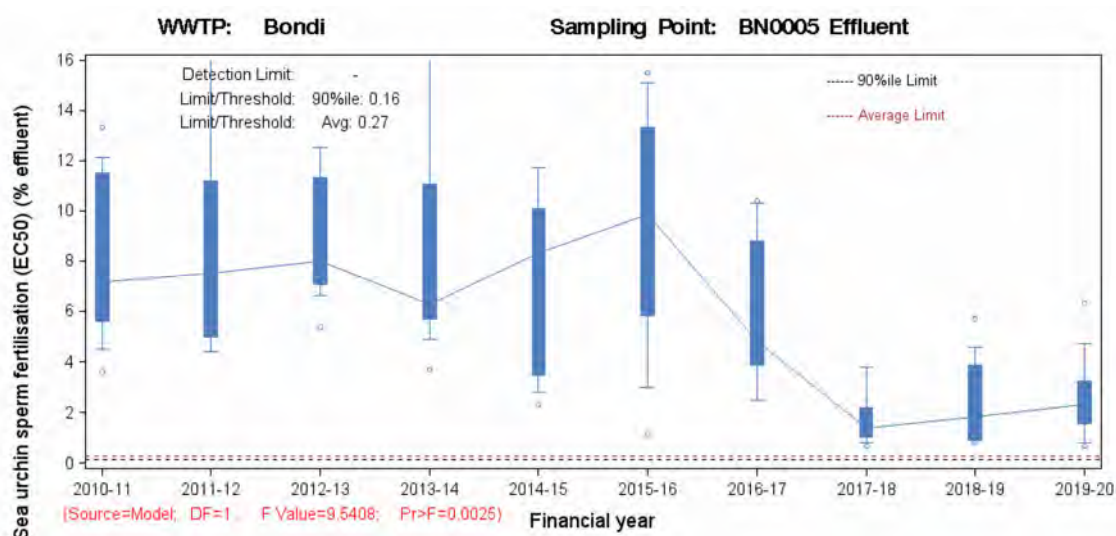
Discharge quality: Major conventional analytes



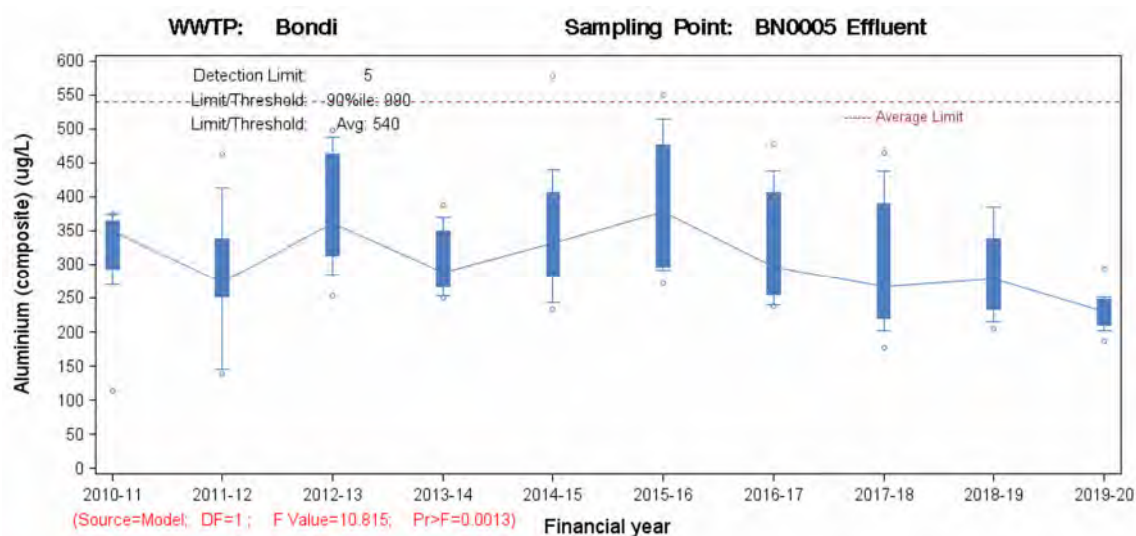
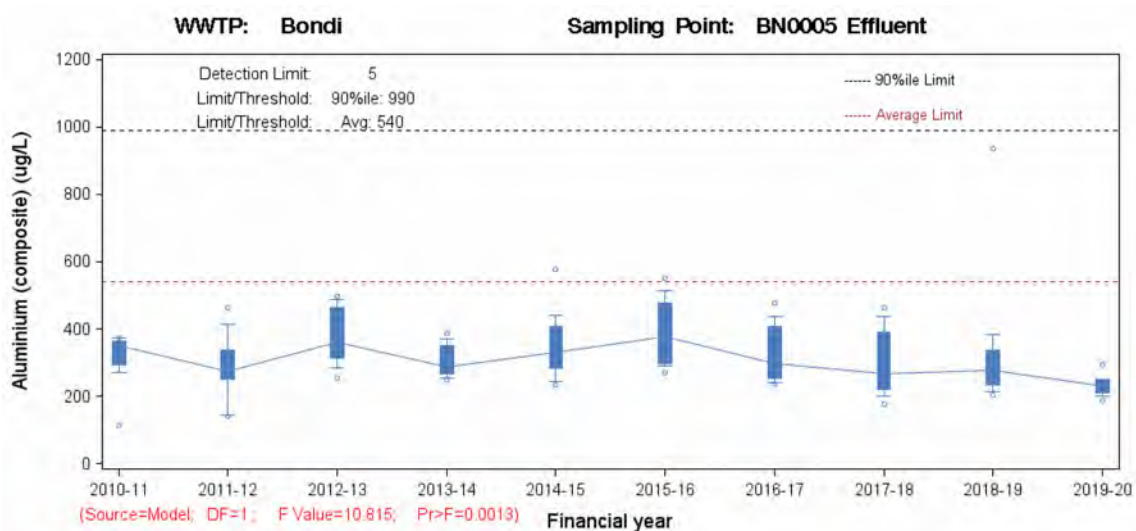


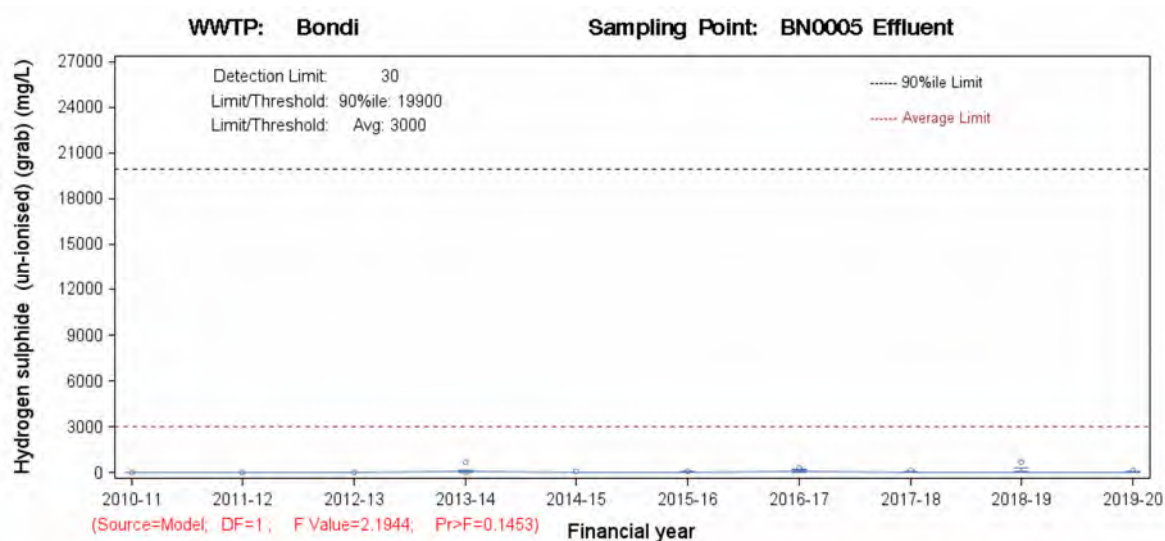
Discharge quality: Toxicity



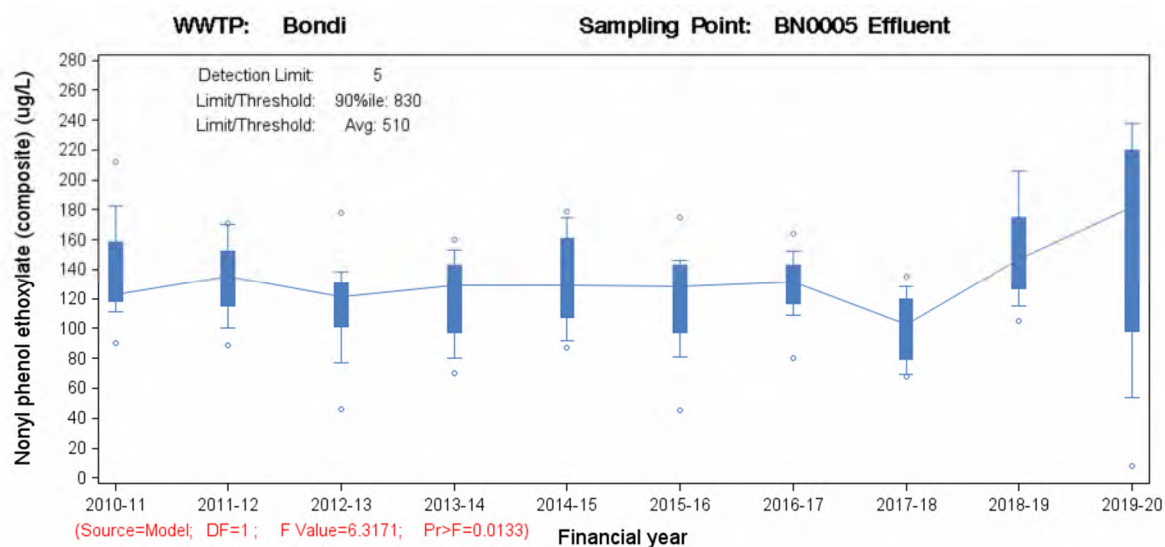
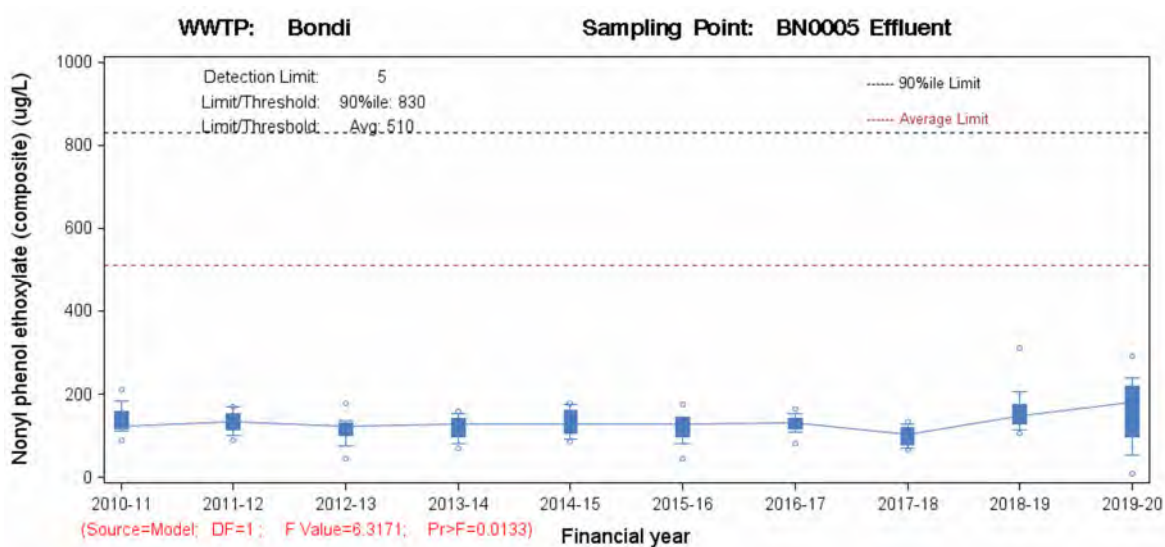


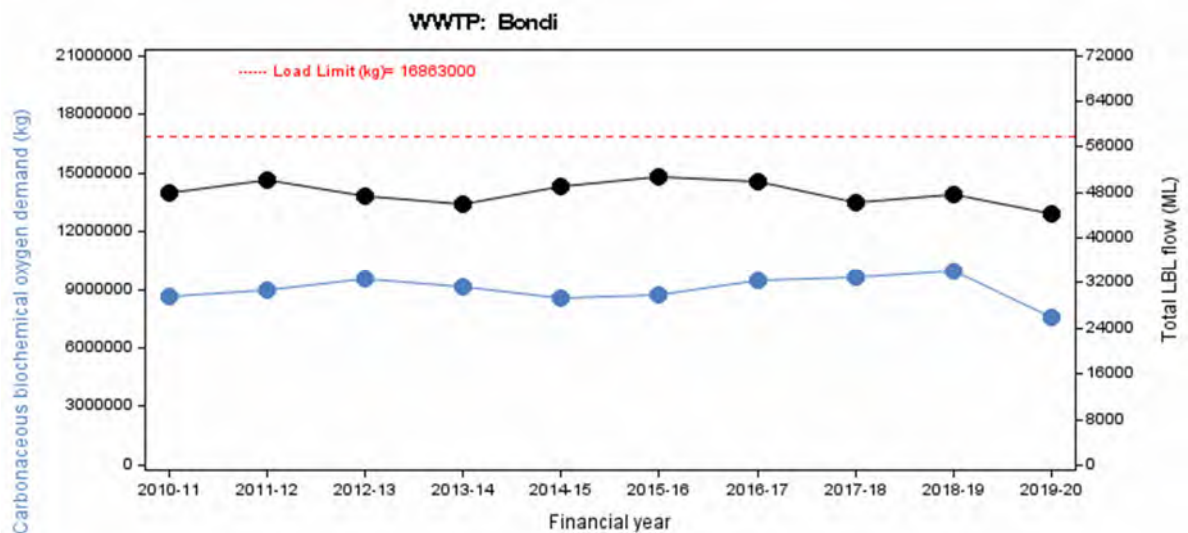
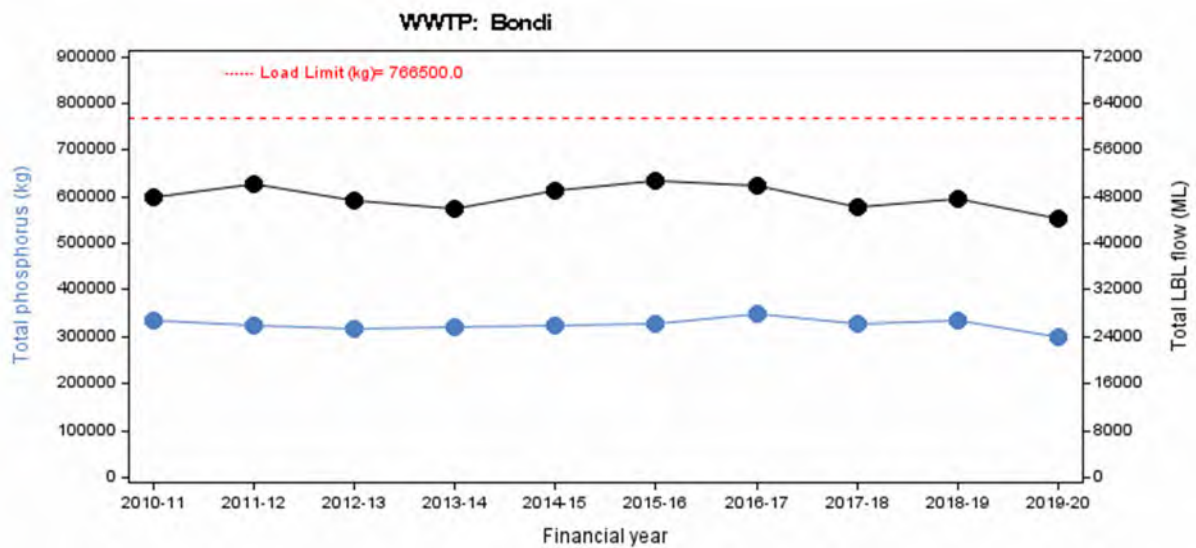
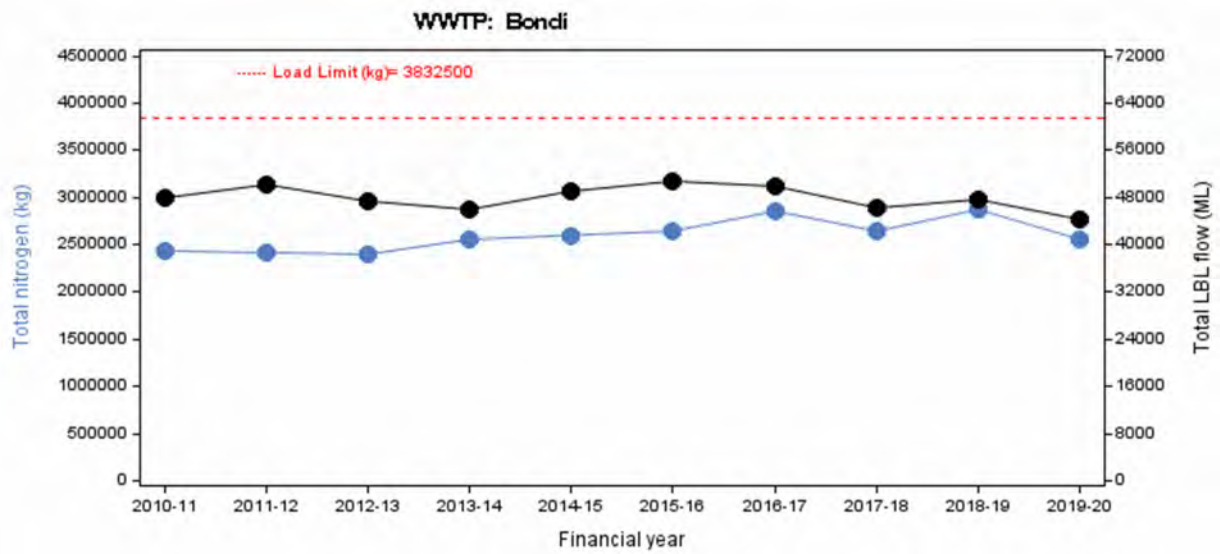
Discharge quality: Trace metals

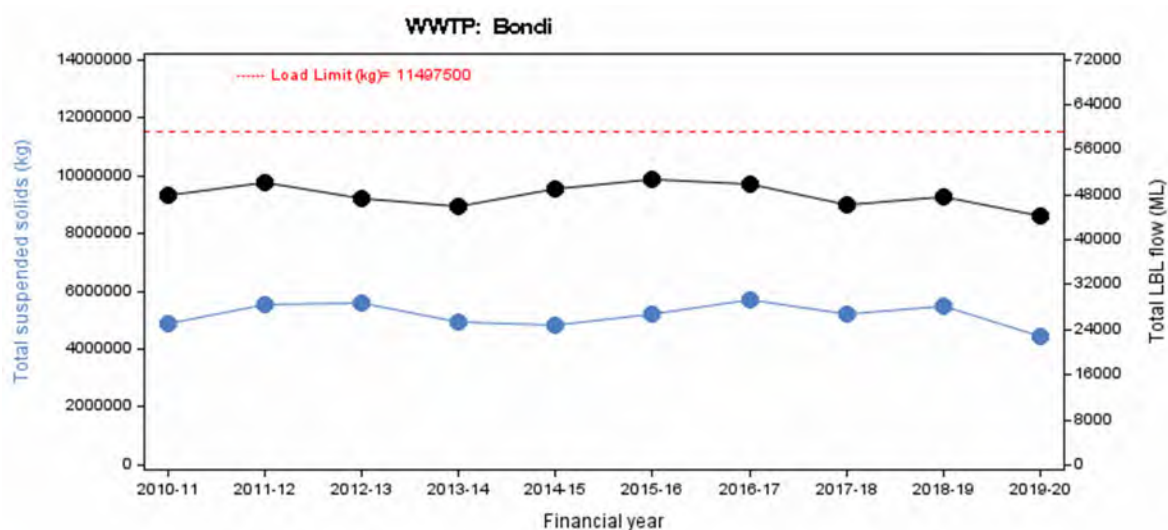
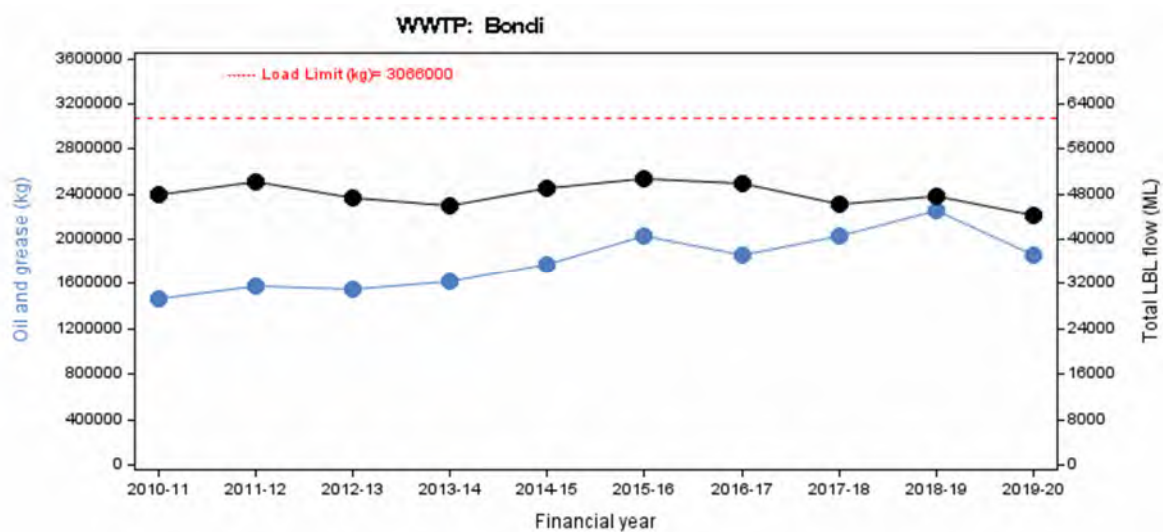




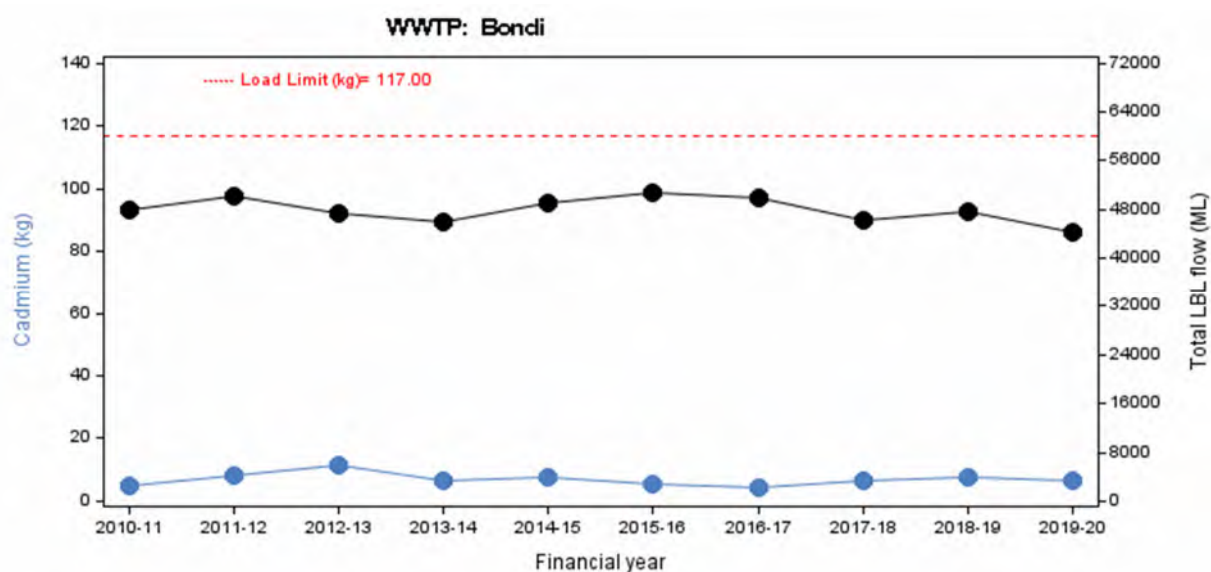
Discharge quality: Other chemicals and organics (including pesticides)

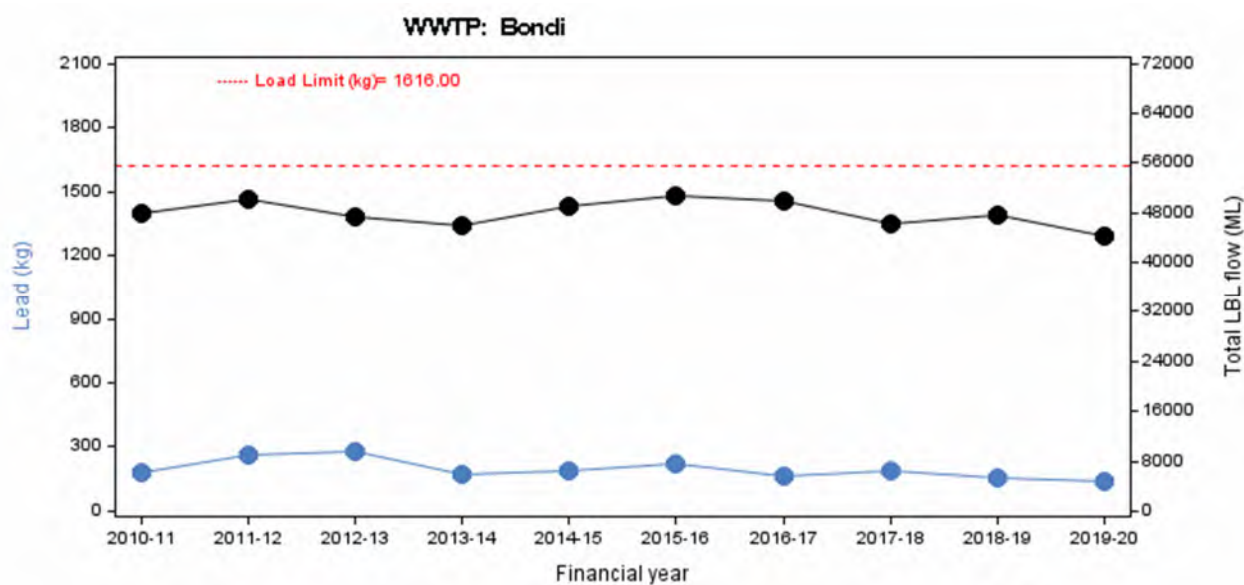
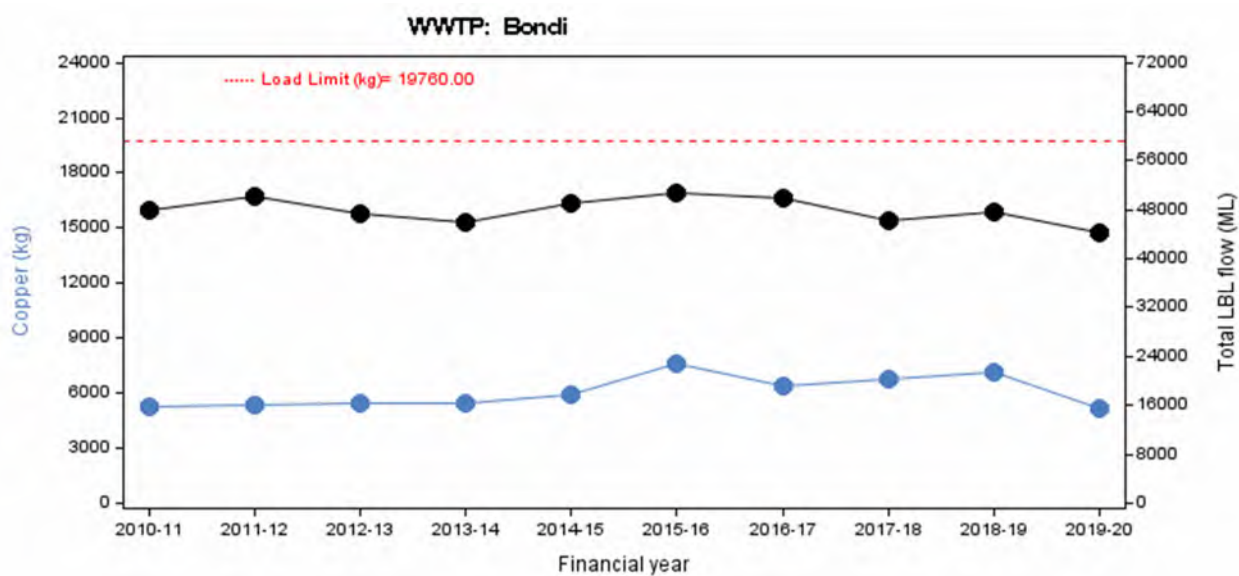
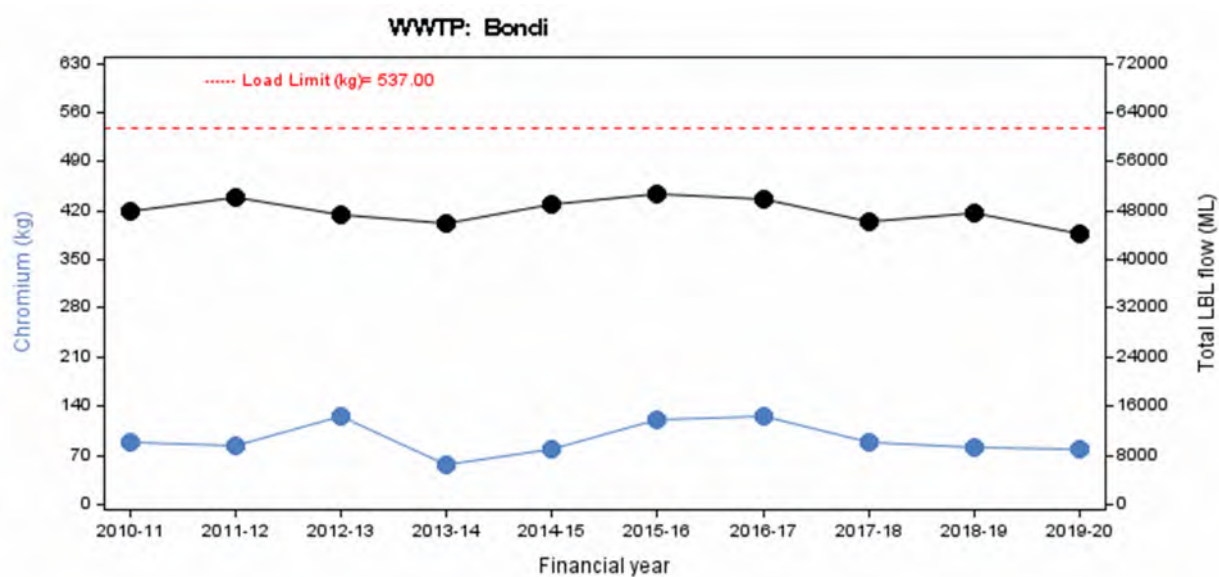


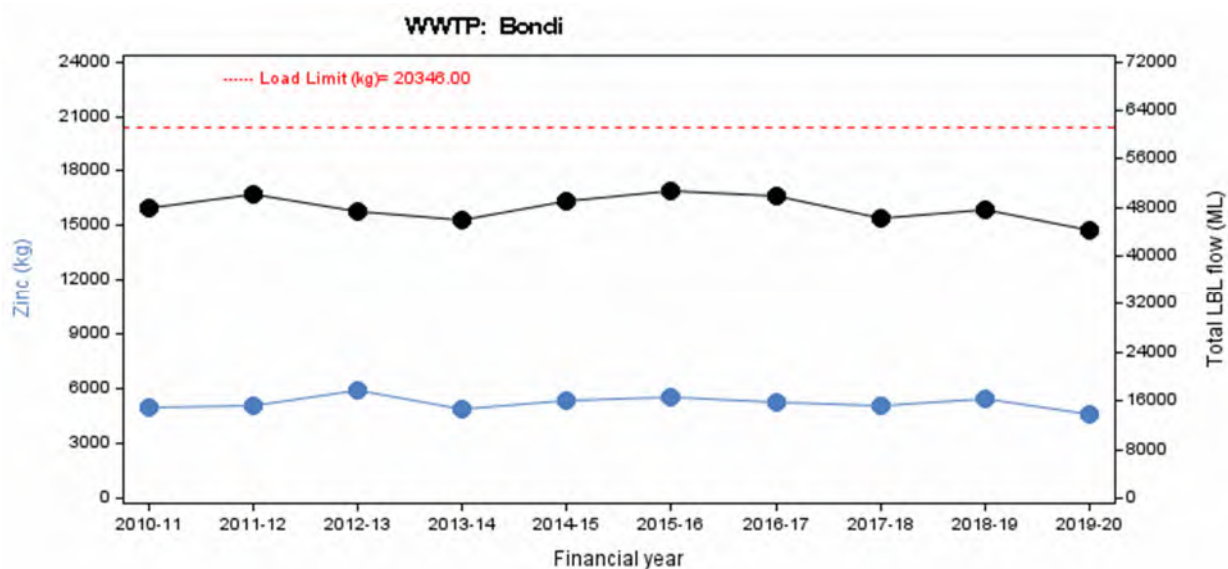
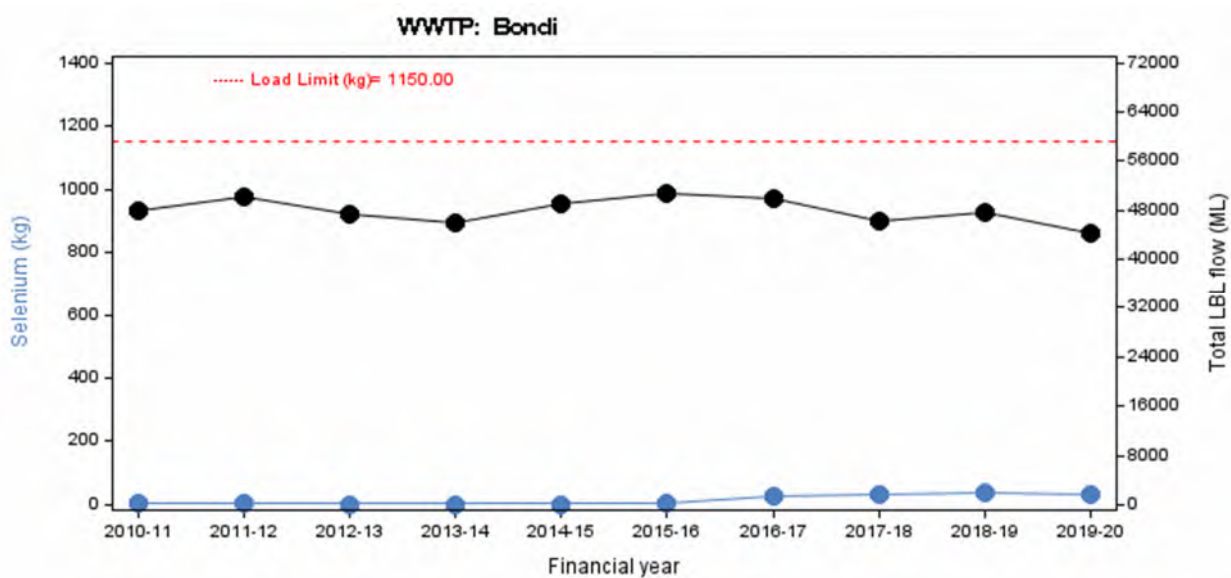
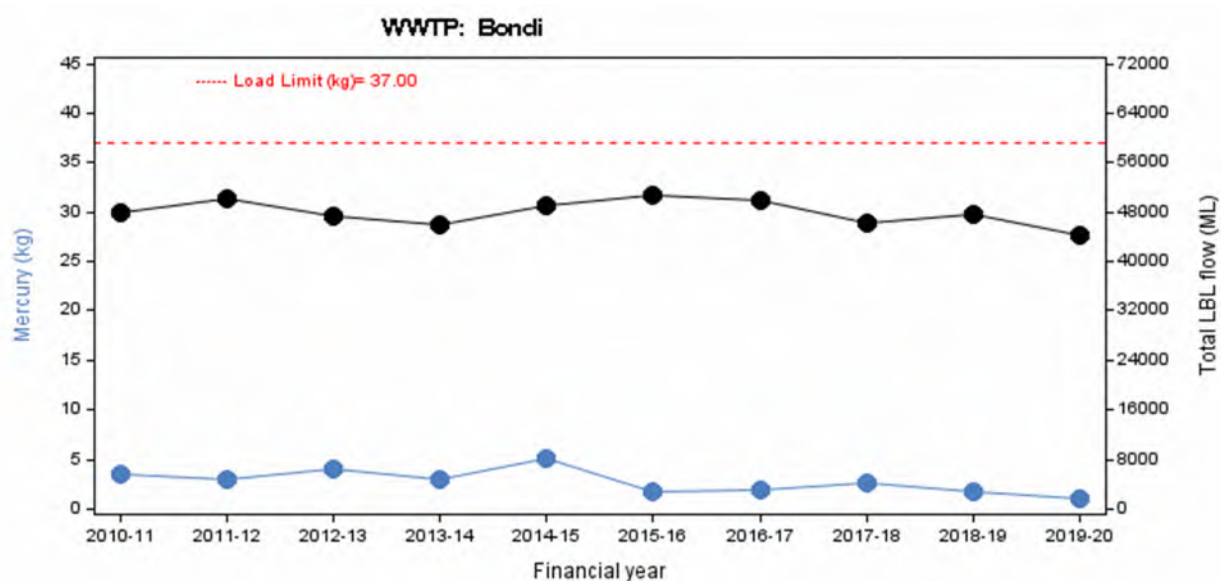


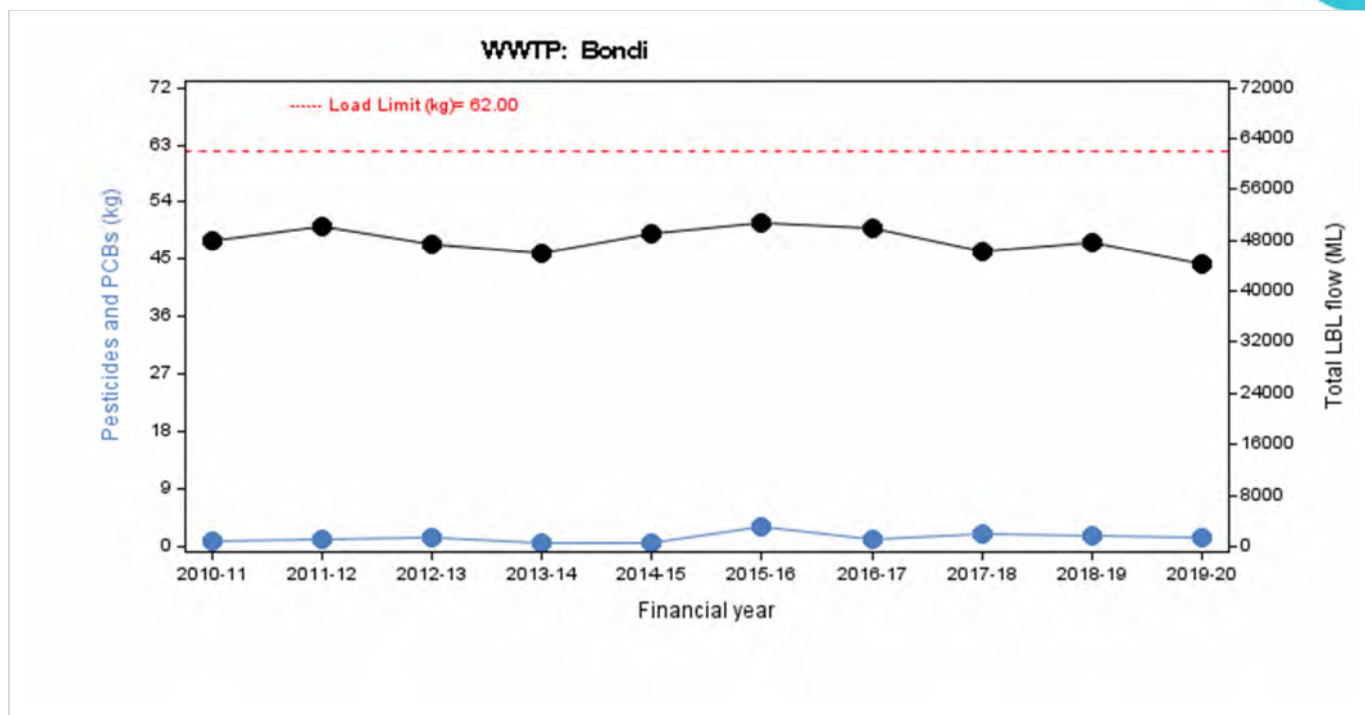


Discharge load: Trace metals





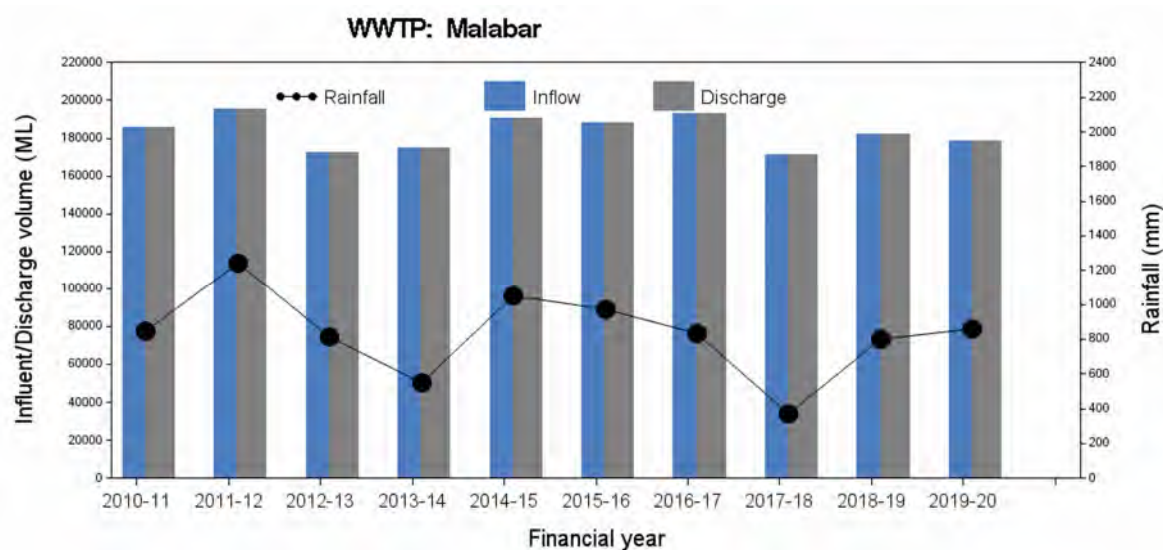




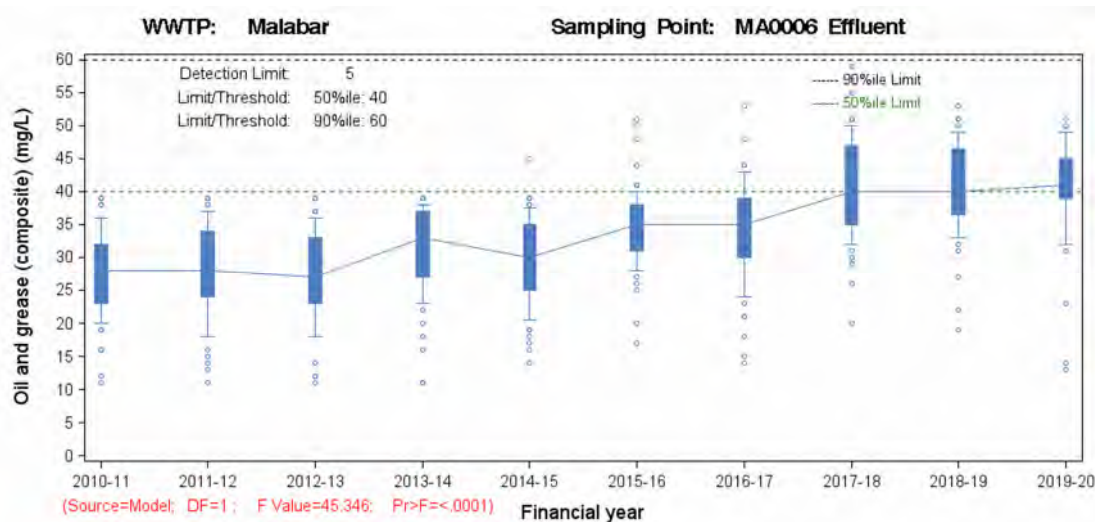
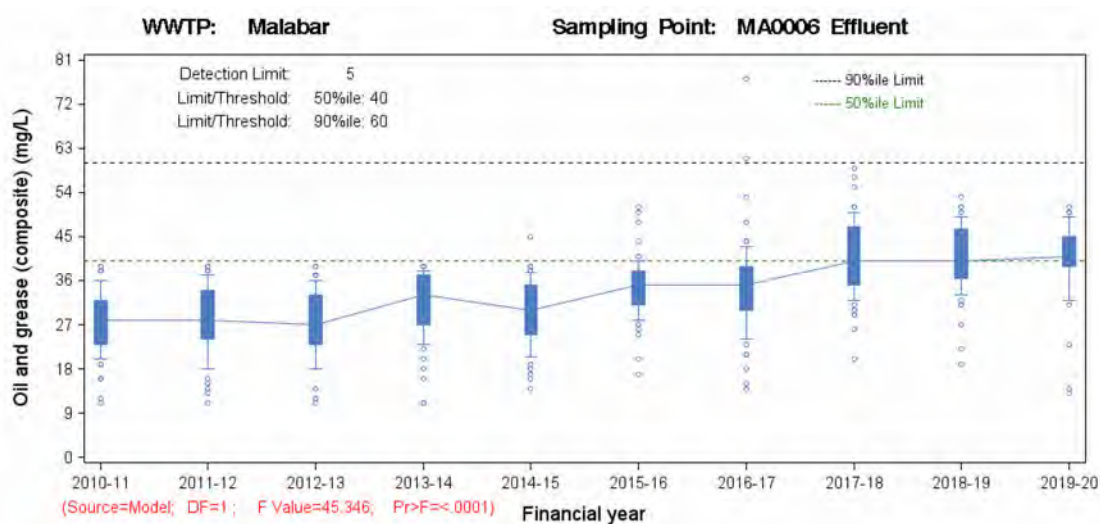
Note: Discharge loads at Bondi WWTP include discharge loads from network (Diamond Bay and Vacluse outfalls)

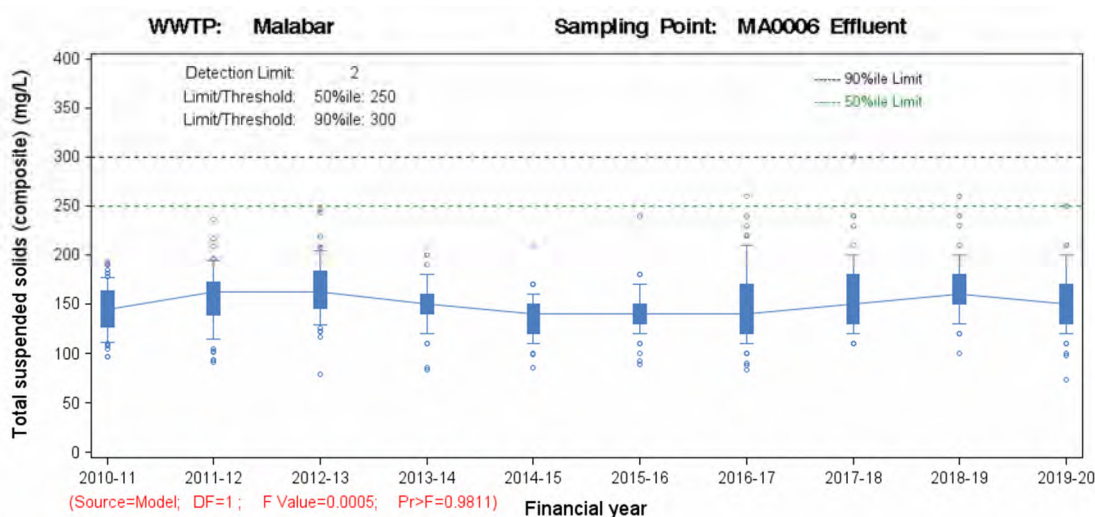
Malabar WWTP

Discharge volume and rainfall

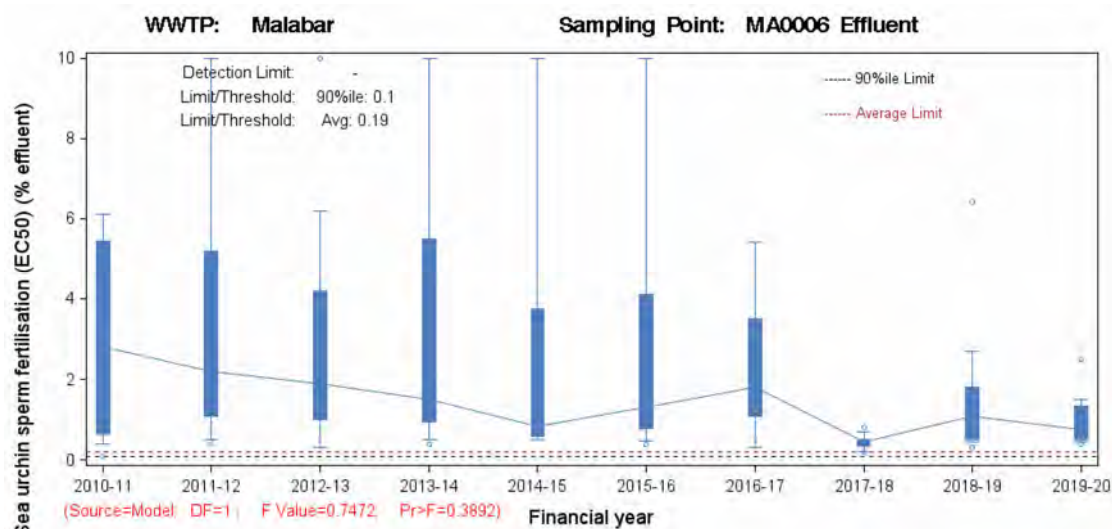


Discharge quality: Major conventional analytes

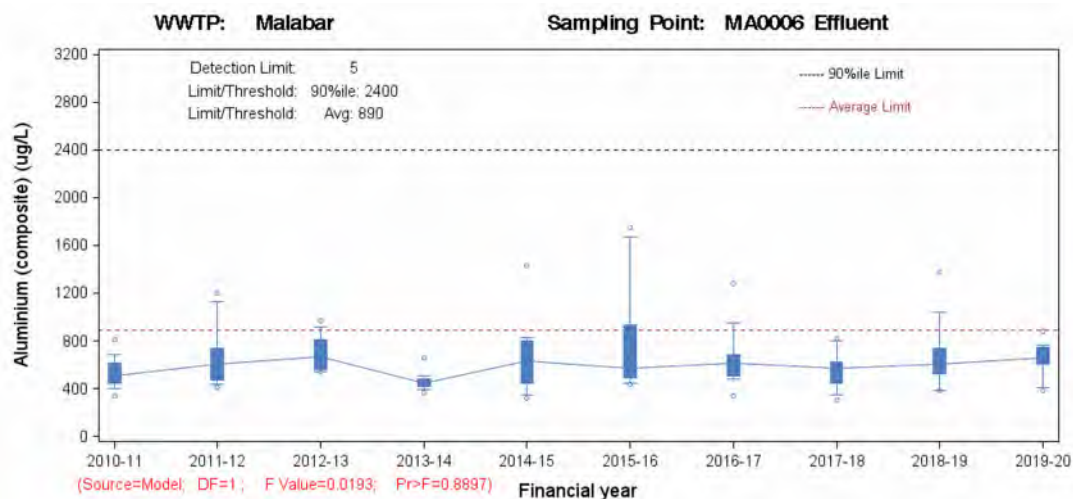


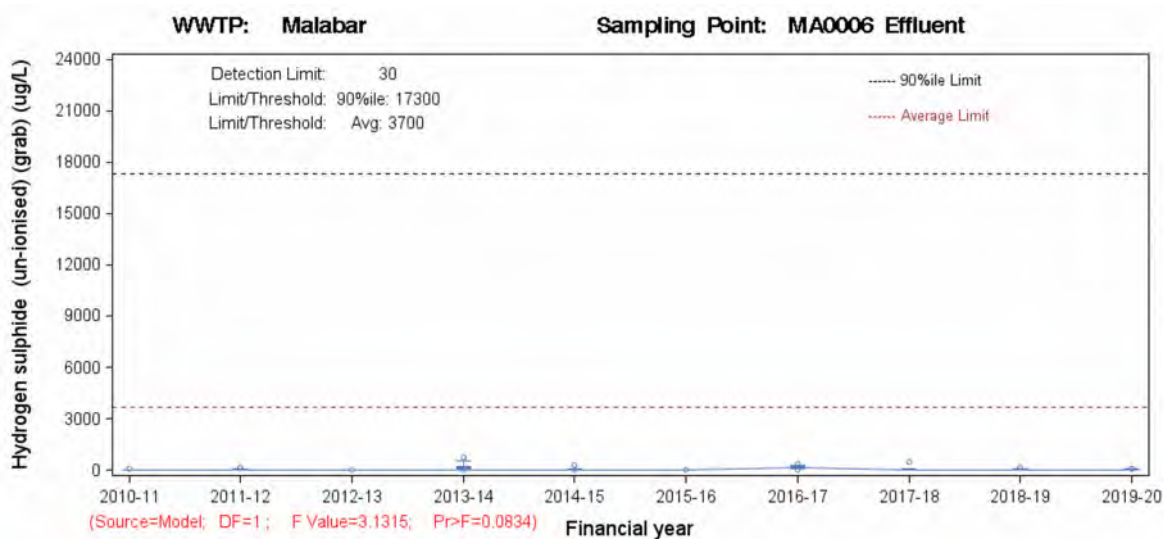


Discharge quality: Toxicity

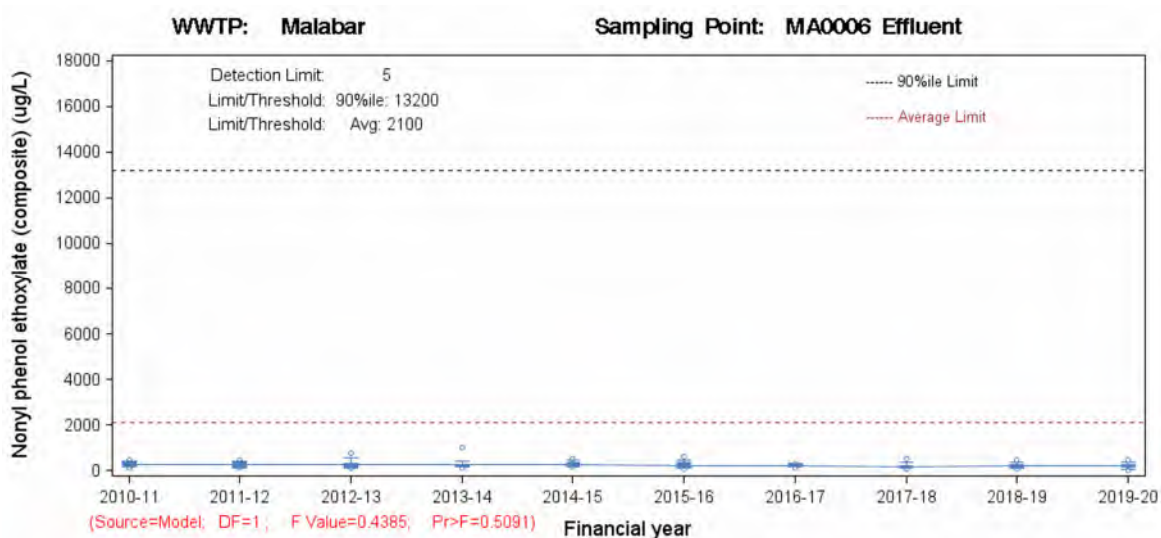


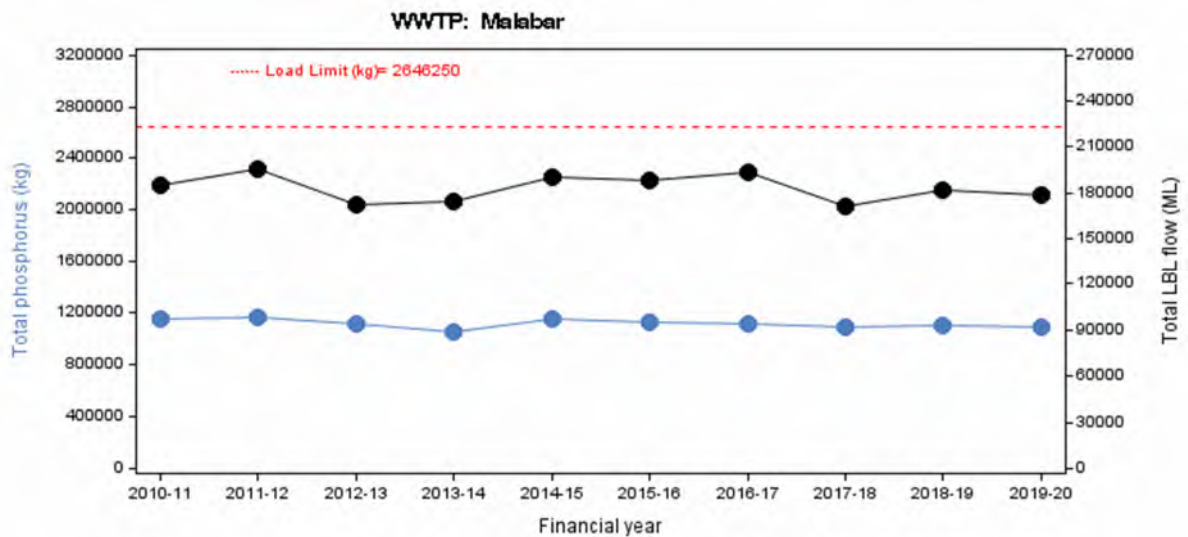
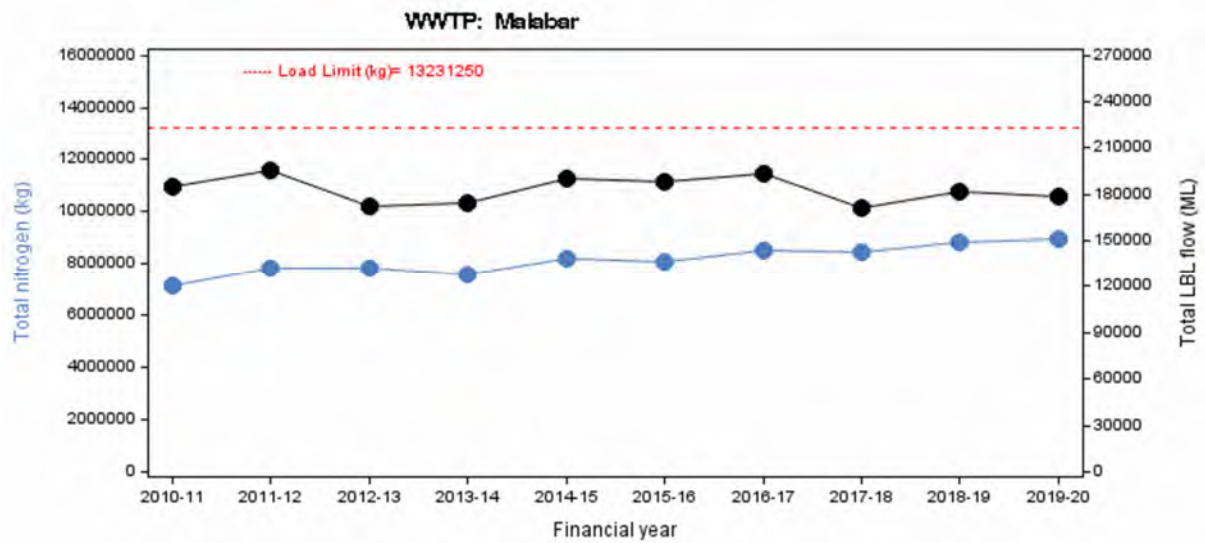
Discharge quality: Trace metals



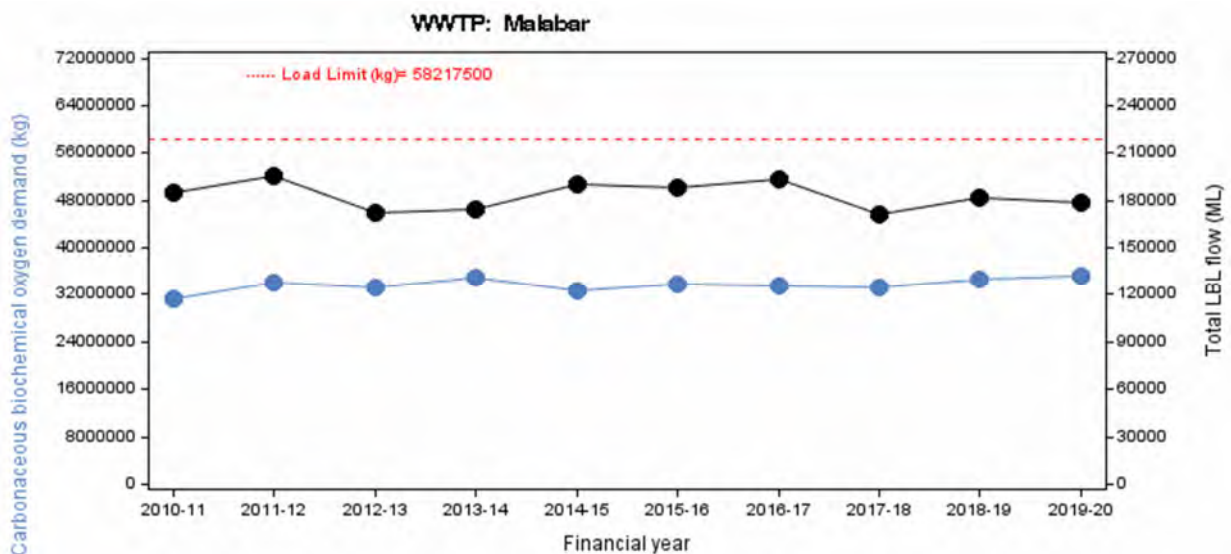


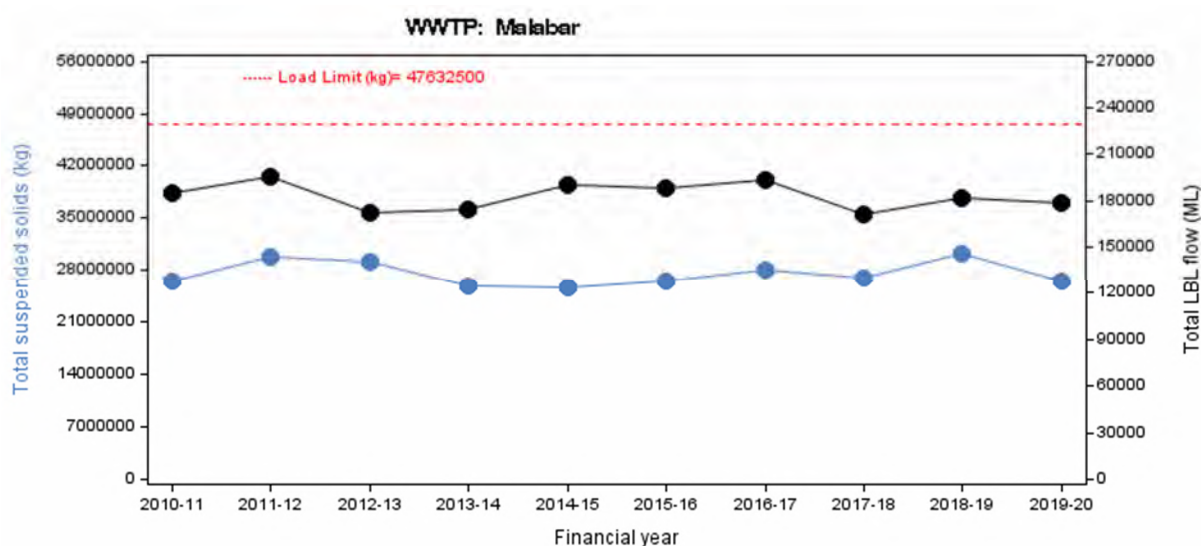
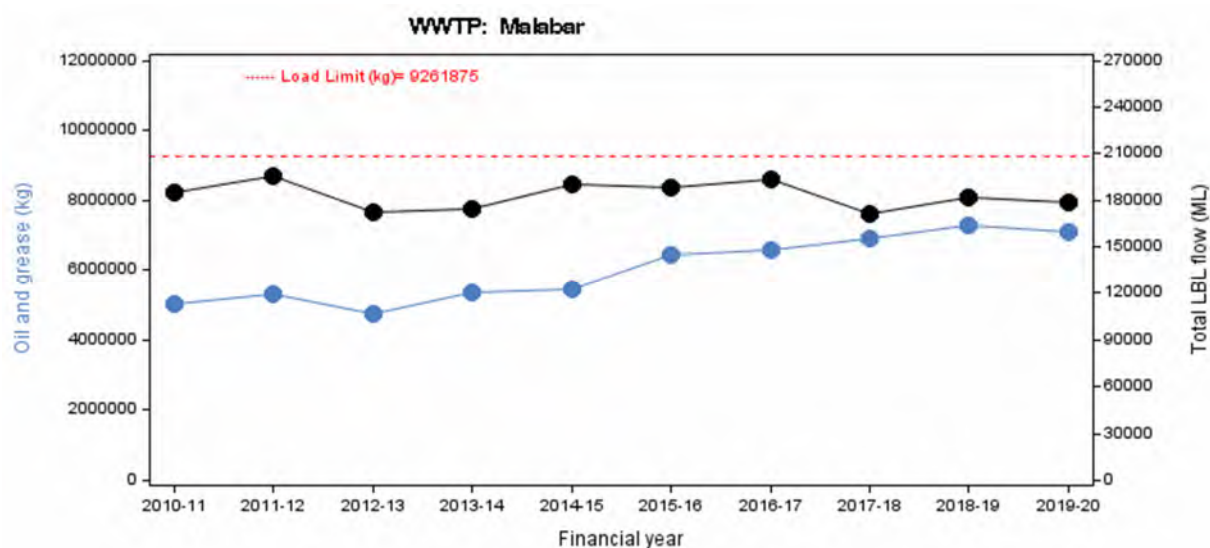
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.



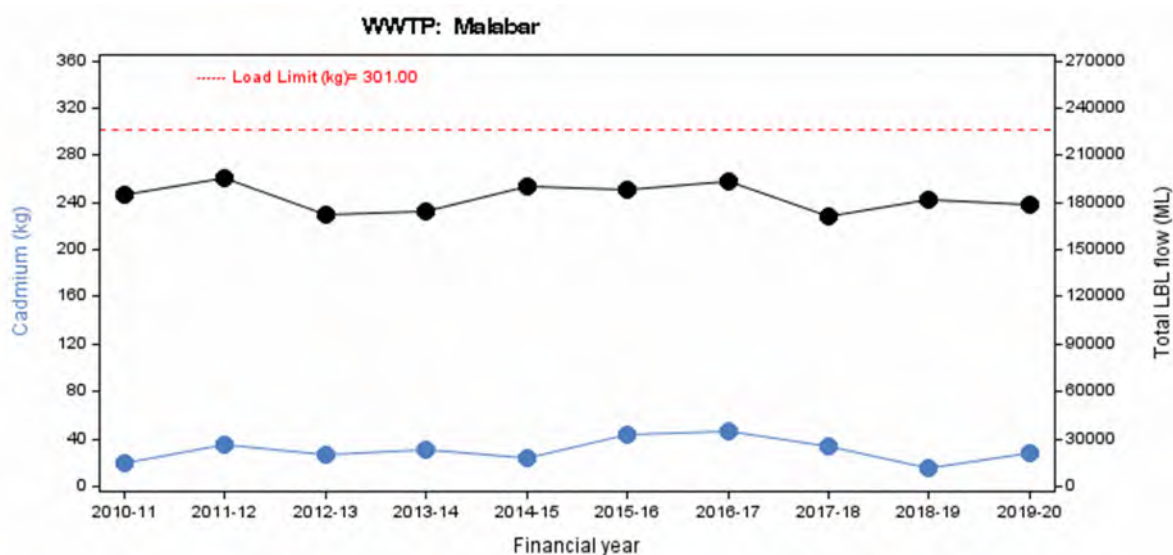


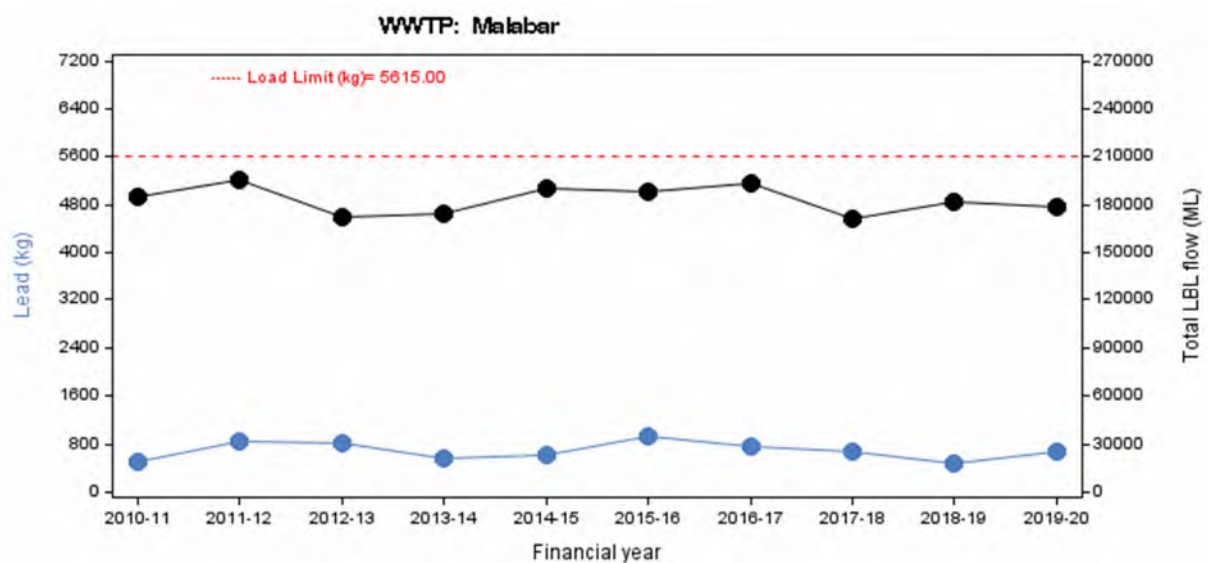
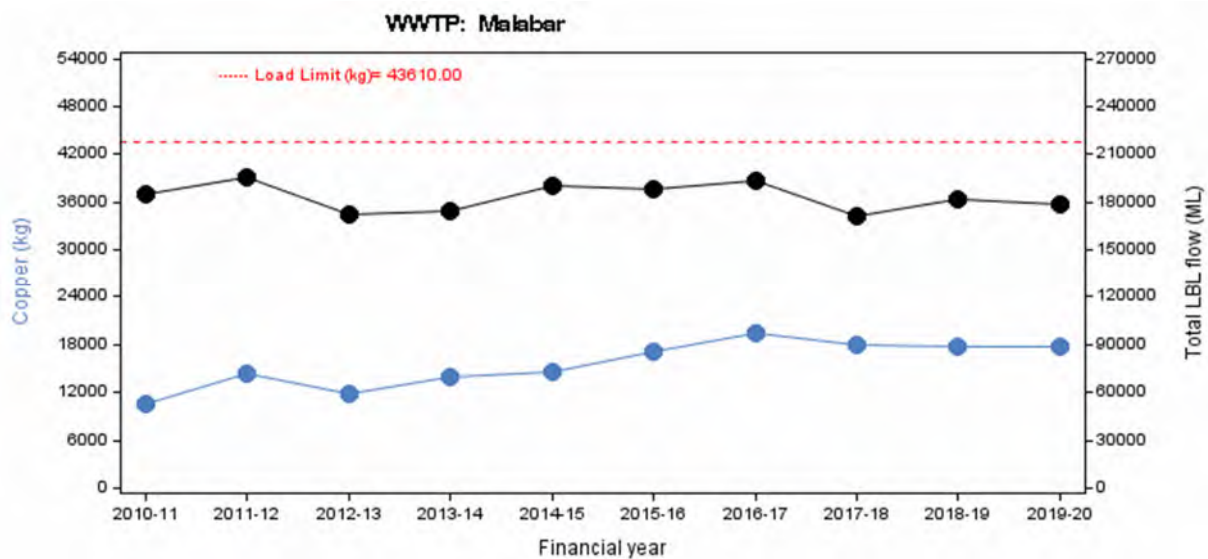
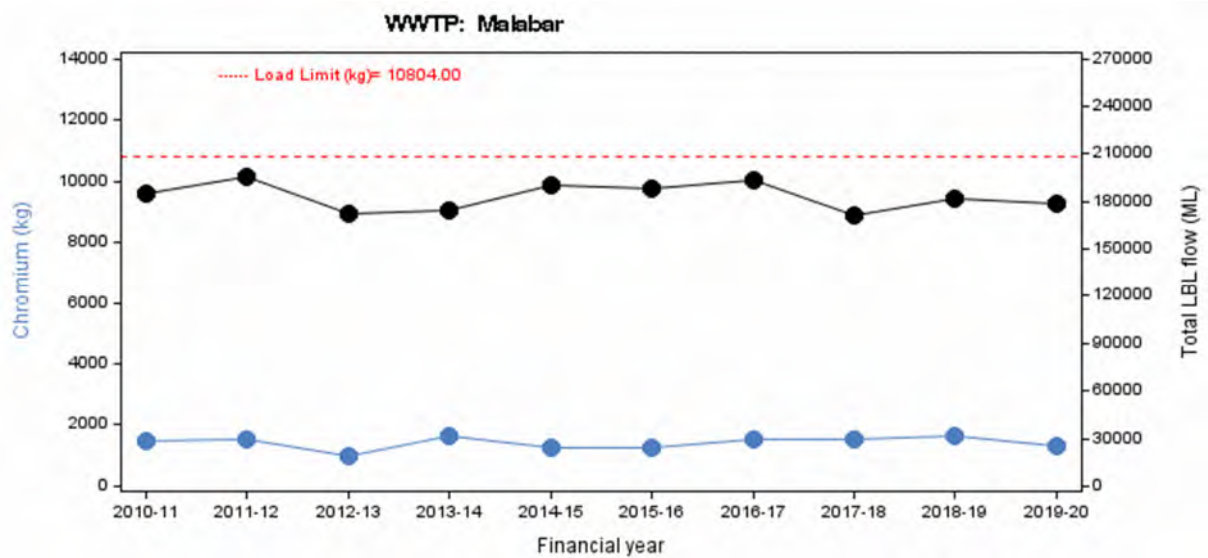
Discharge load: Major conventional analytes

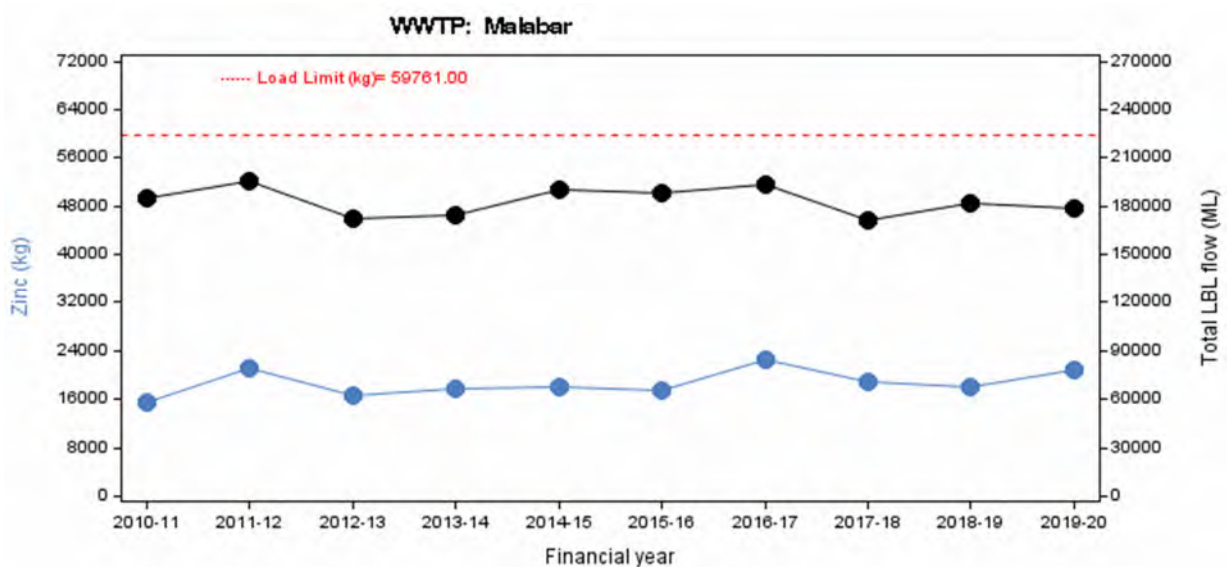
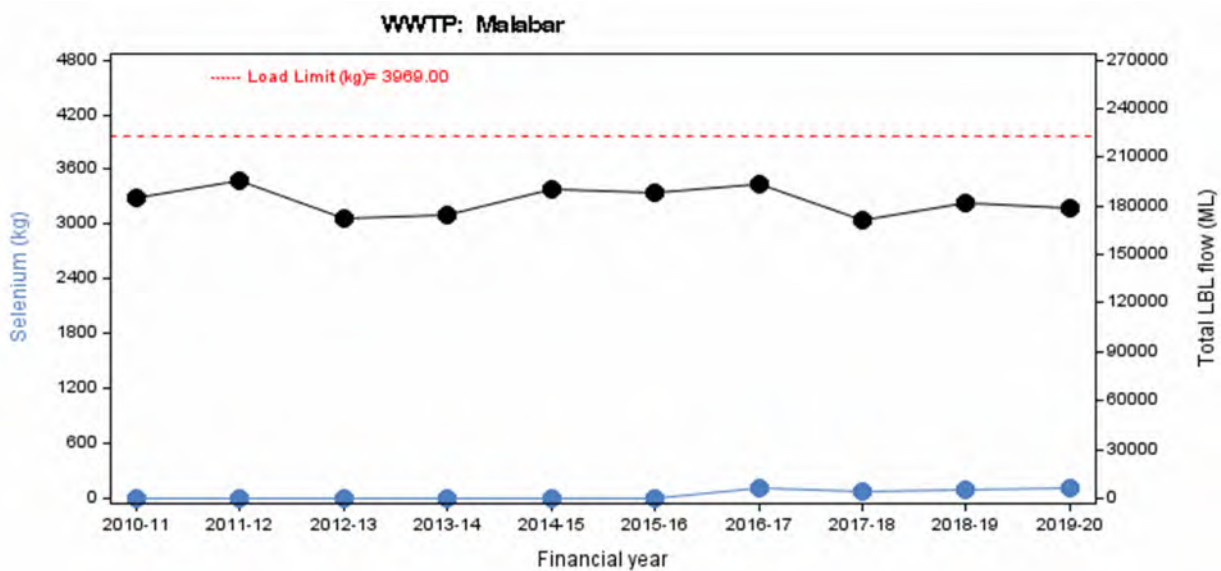
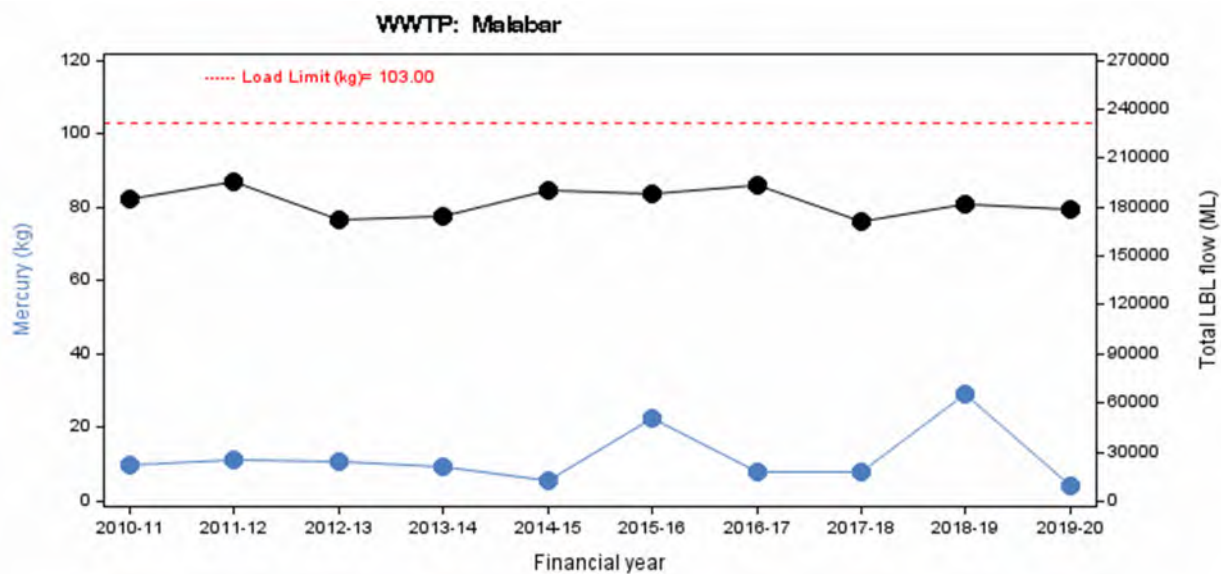




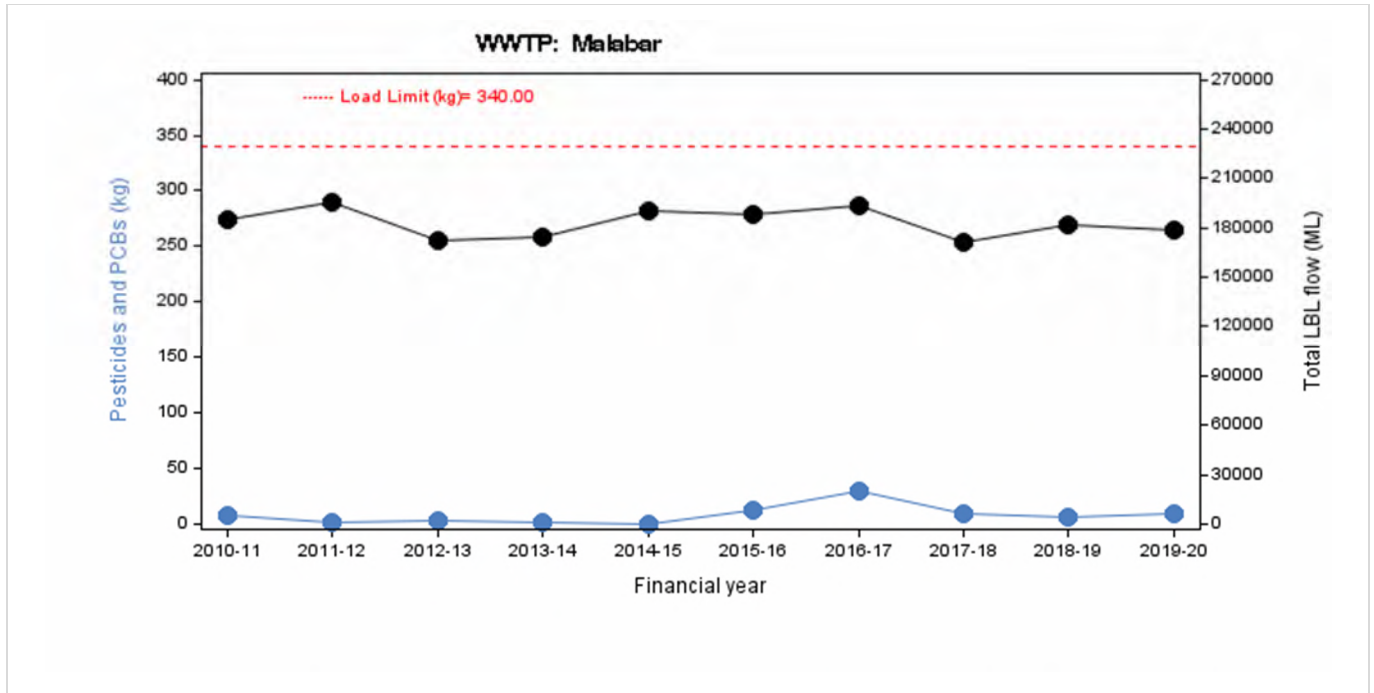
Discharge load: Trace Metals





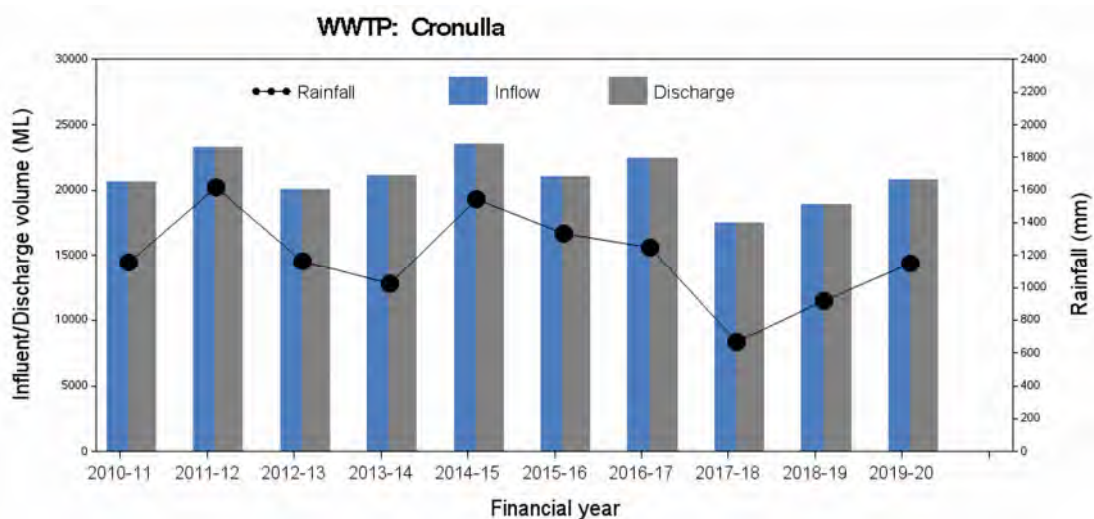


Discharge load: Other chemicals and organics (including pesticides)

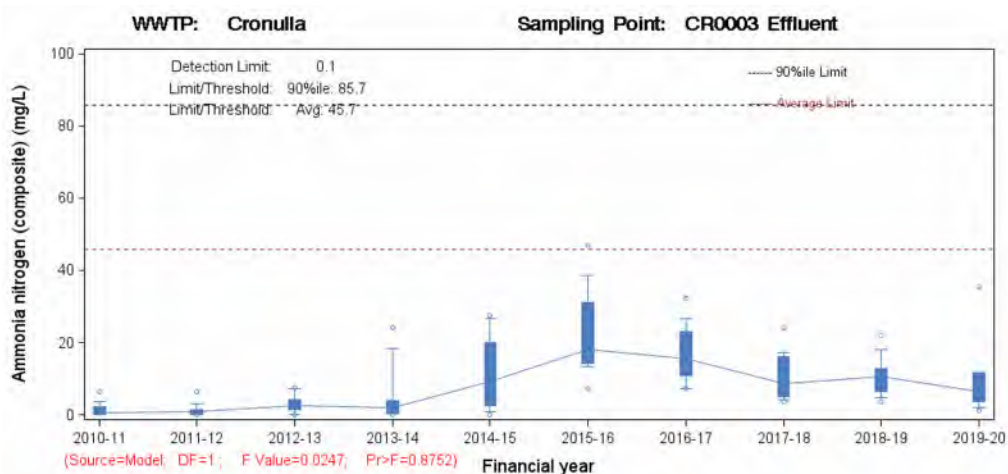


Cronulla WWTP

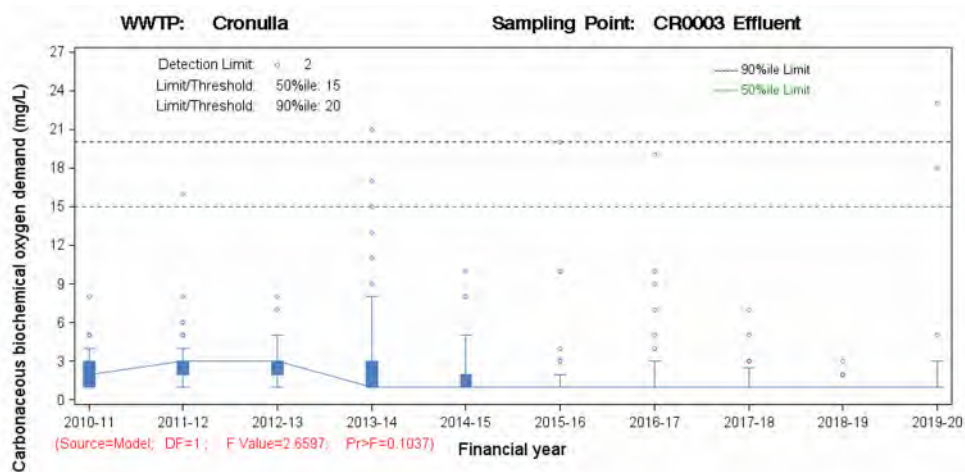
Discharge volume and rainfall



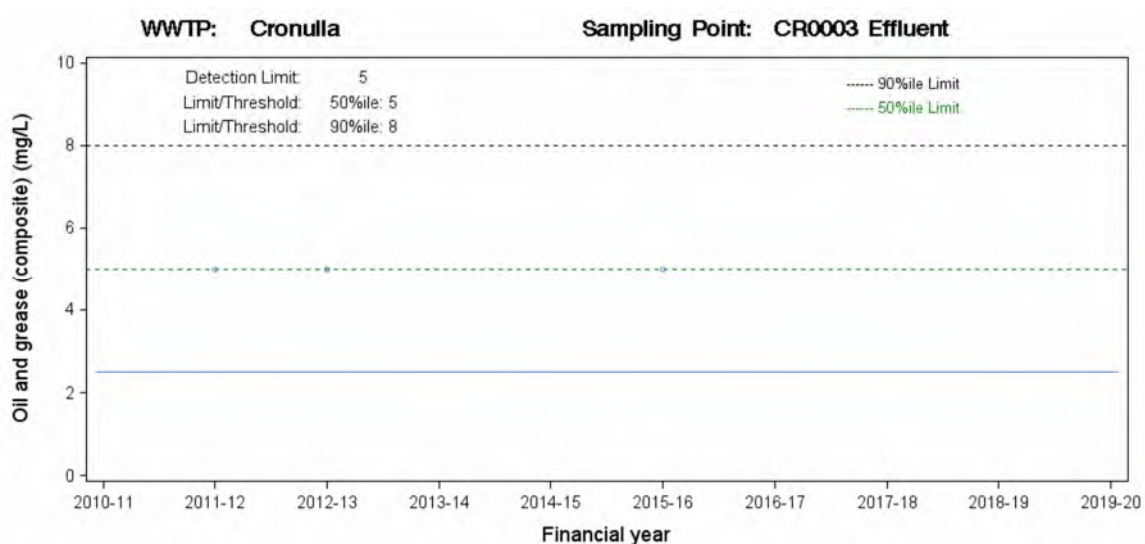
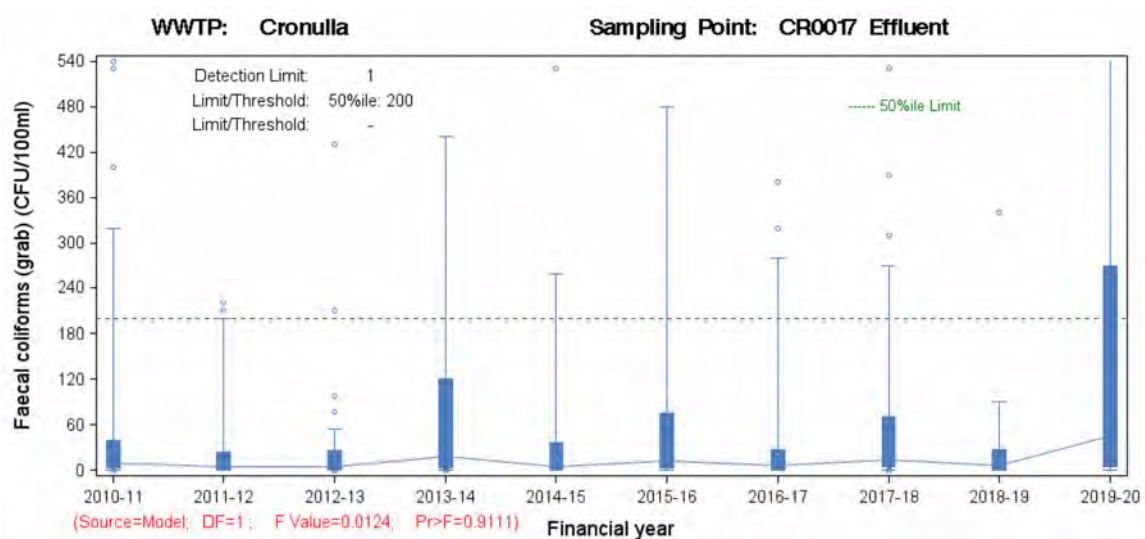
Discharge quality: Nutrients



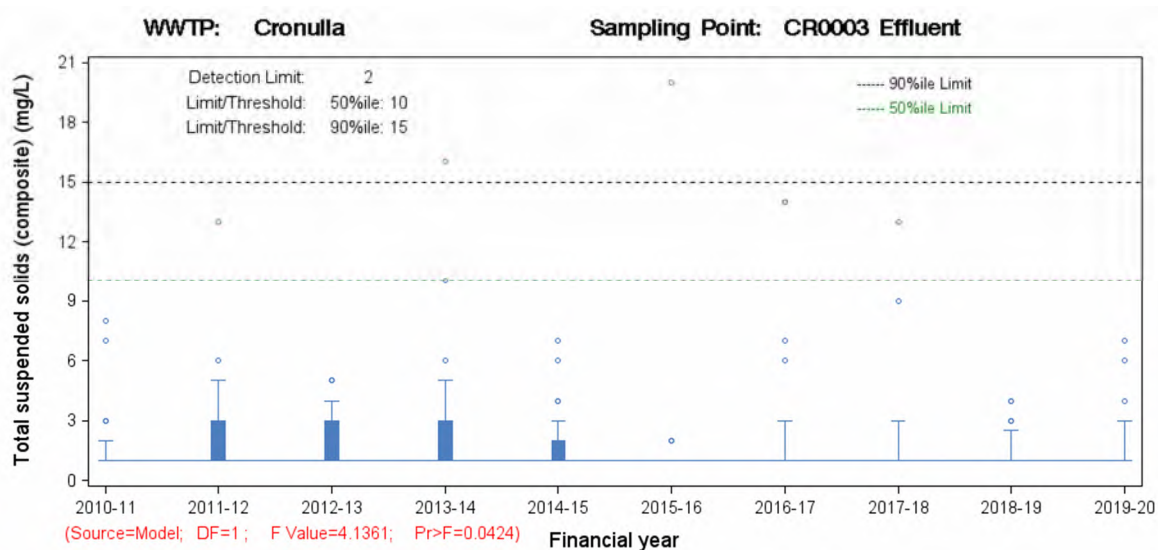
Discharge quality: Major conventional analytes

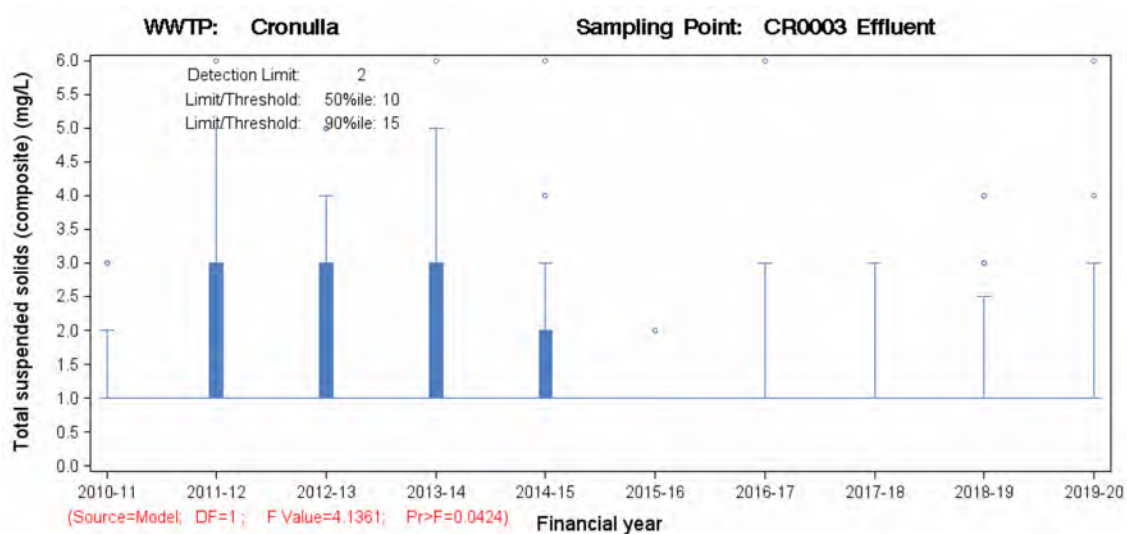


Note: Statistical test was based on 2019-20 data with previous five years data (2014-2019) due to lab method change in 2014-15.

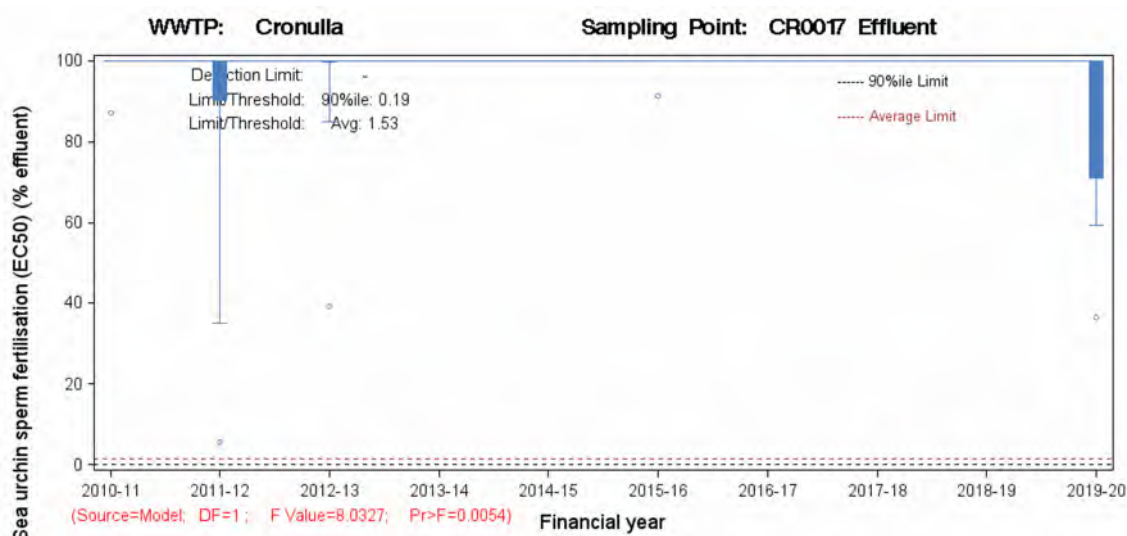
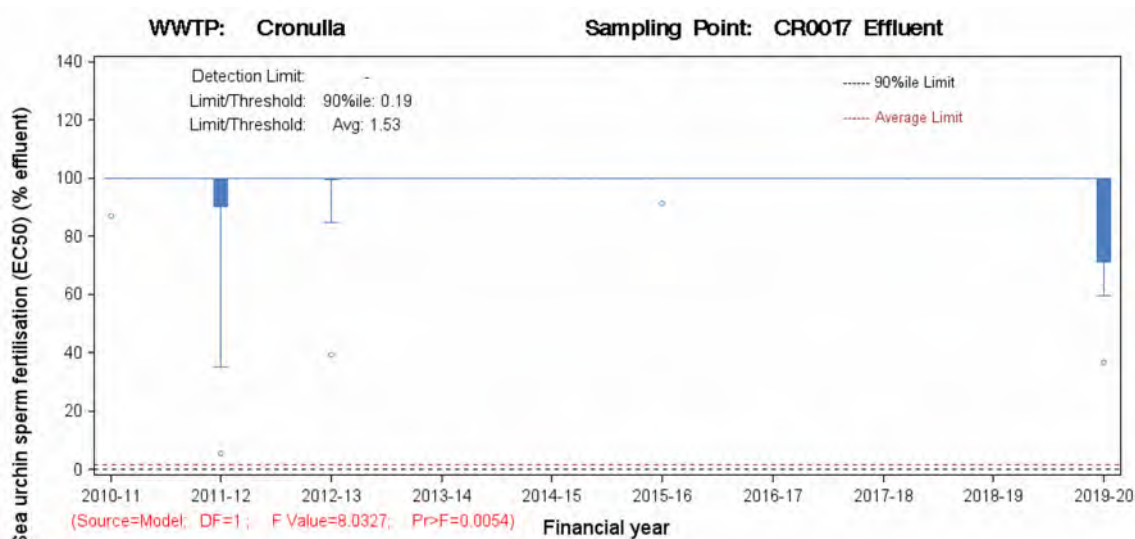


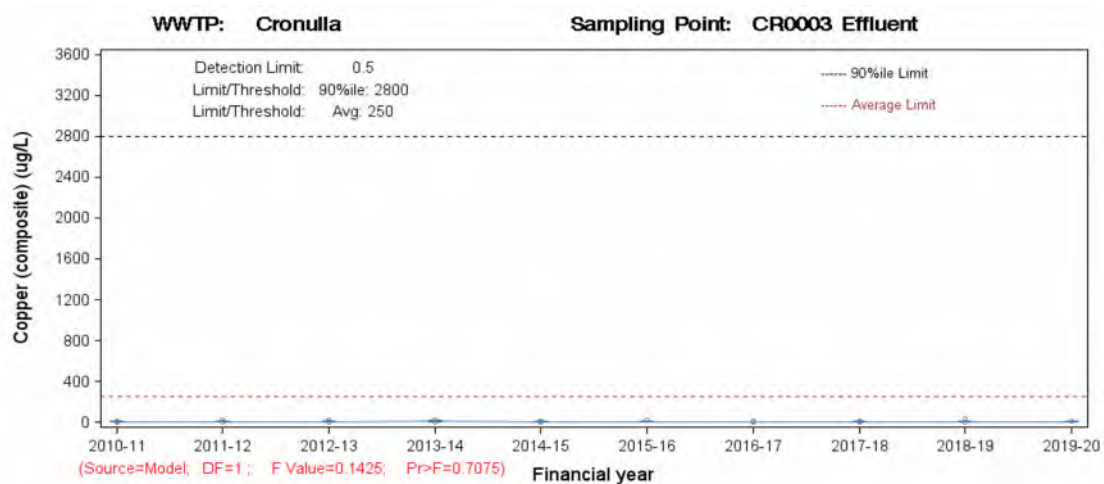
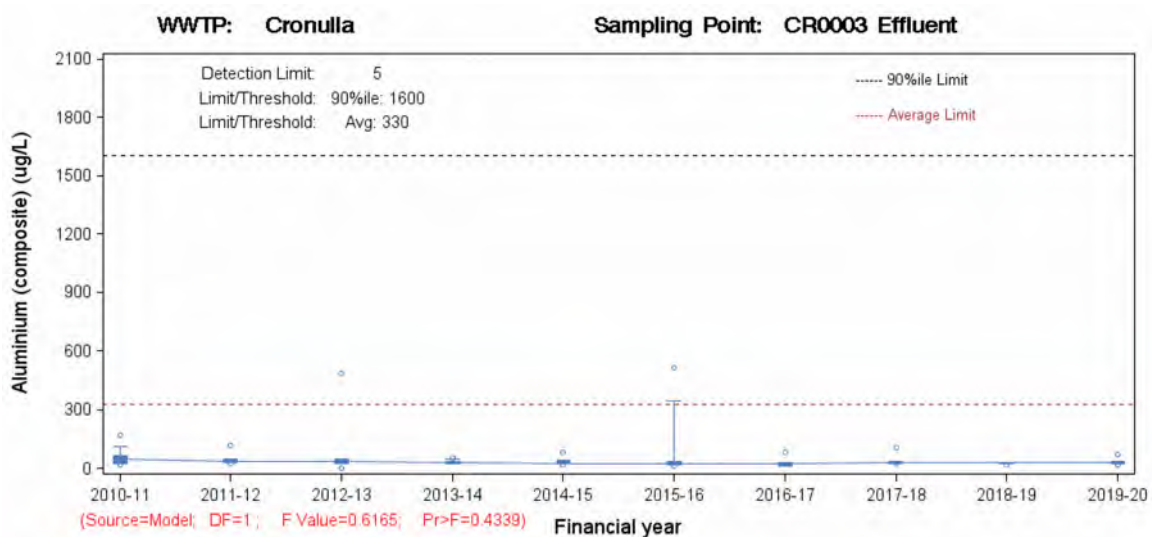
Note: Statistical test was not conducted because >90% of results were below the detection limit.



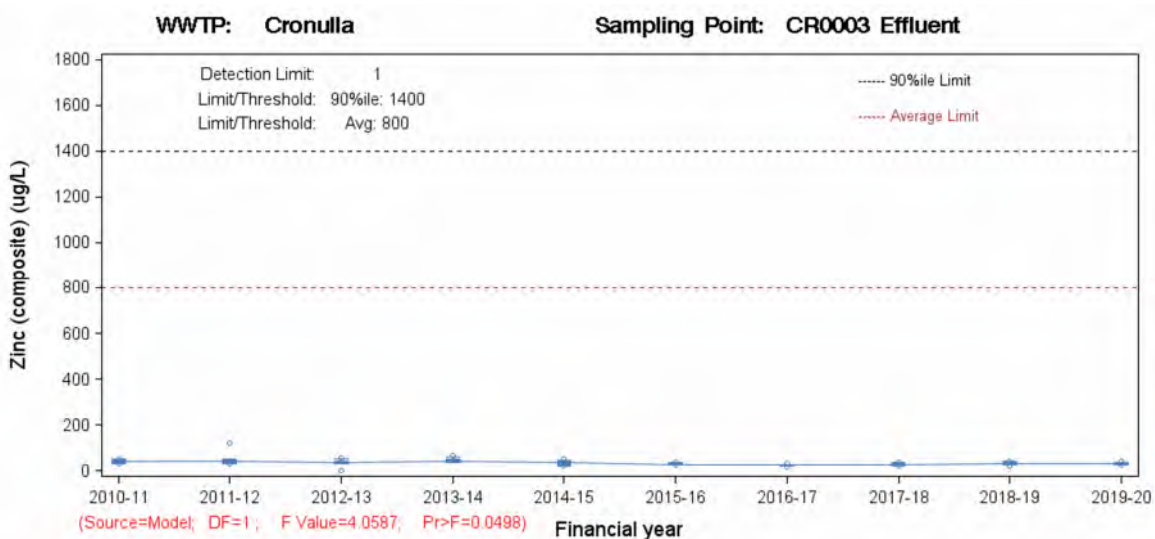


Discharge quality: Toxicity

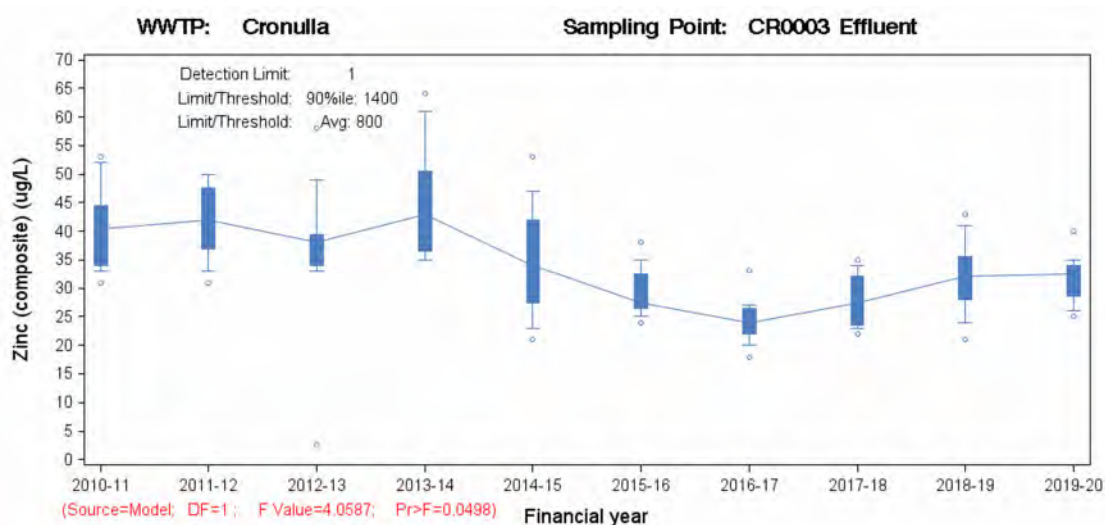




Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

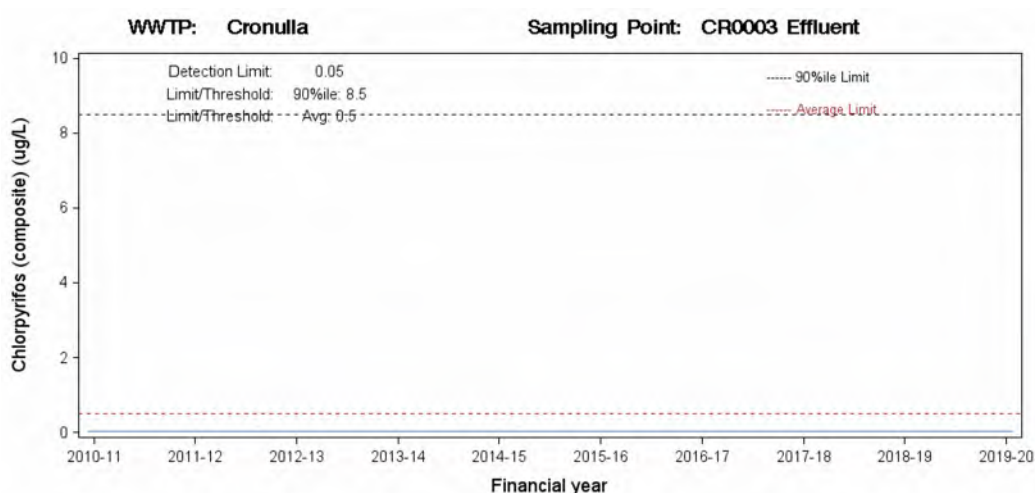


Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

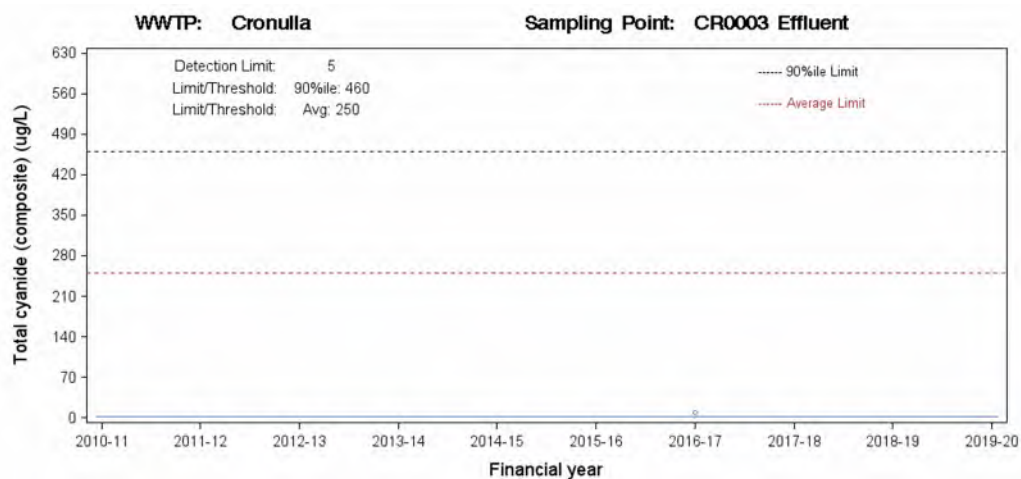


Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

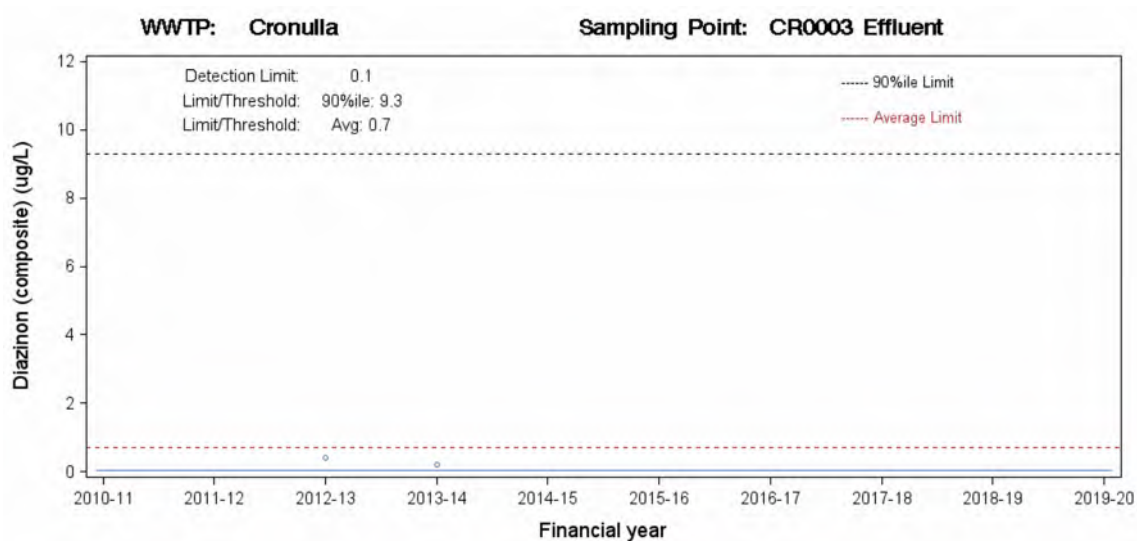
Discharge quality: Other chemicals and organics (including pesticides)



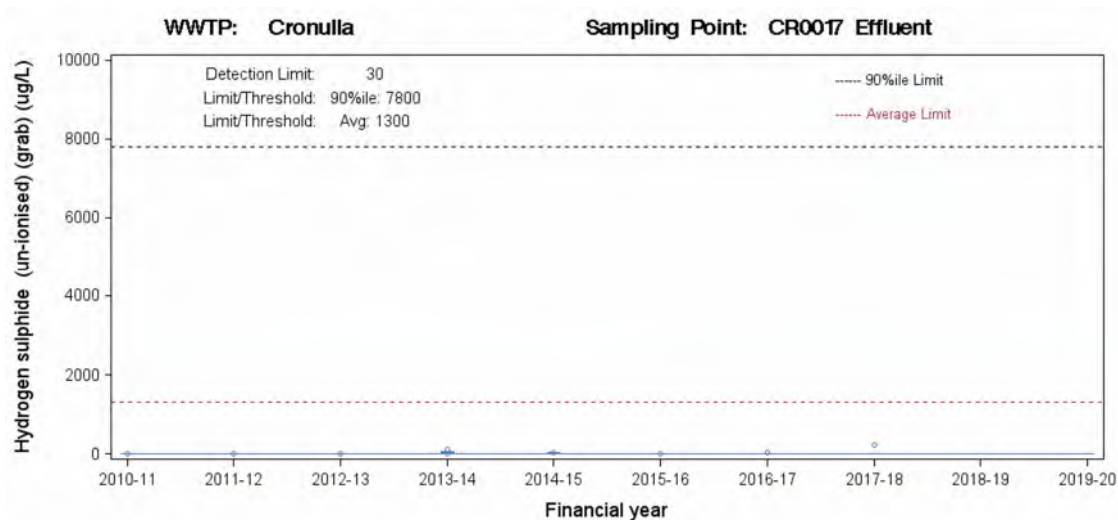
Note: Statistical test was not conducted because >90% of results were below the detection limit.



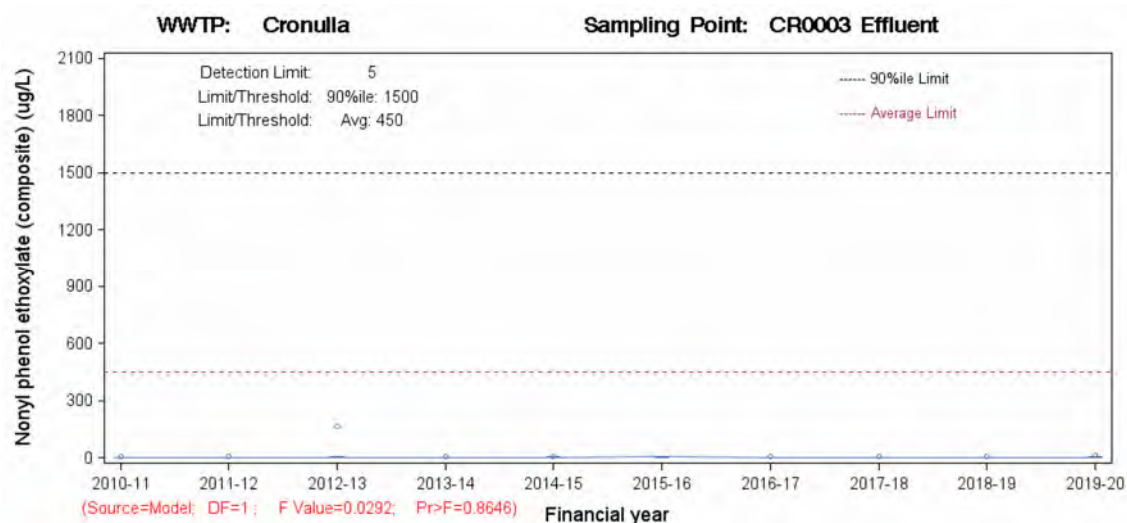
Note: Statistical test was not conducted because >90% of results were below the detection limit.

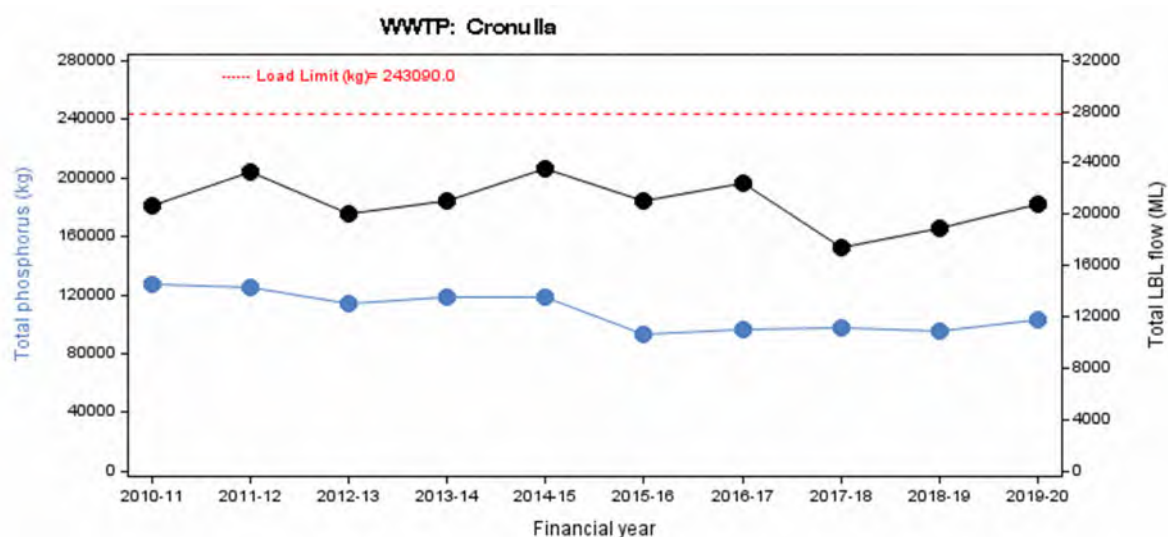
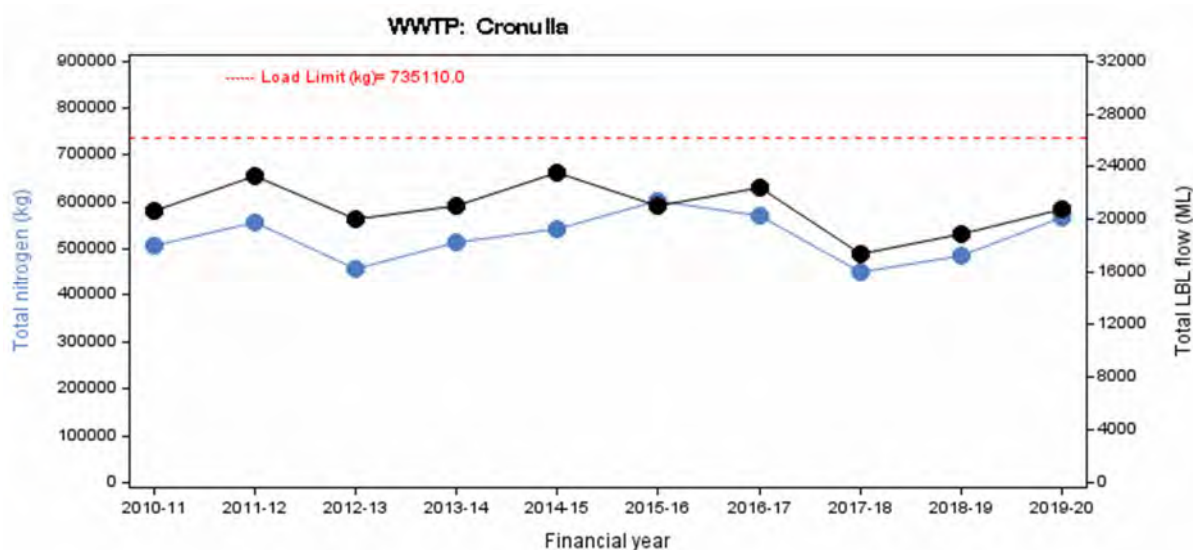


Note: Statistical test was not conducted because >90% of results were below the detection limit.

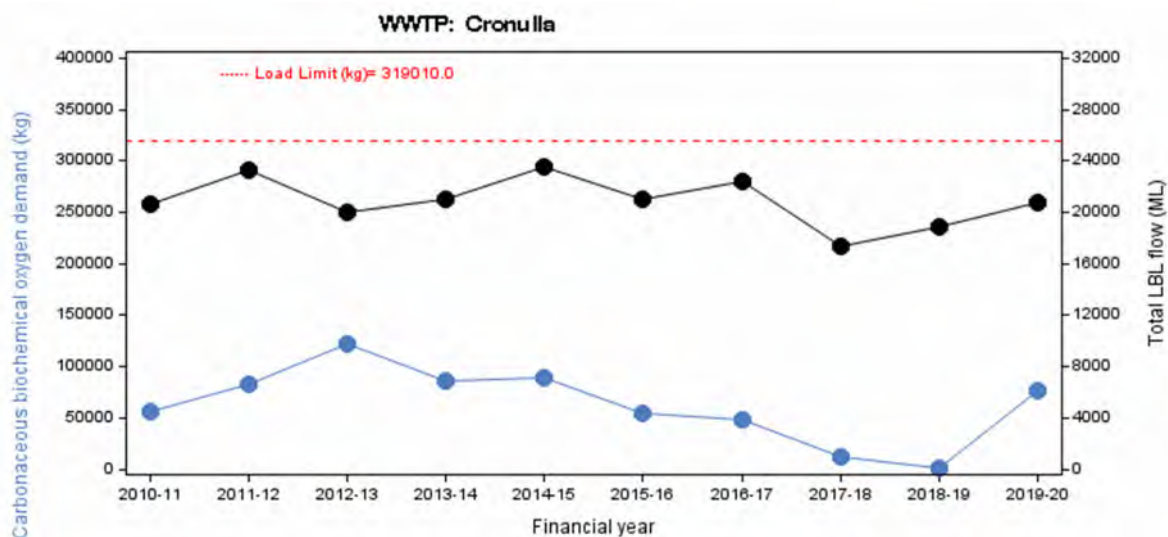


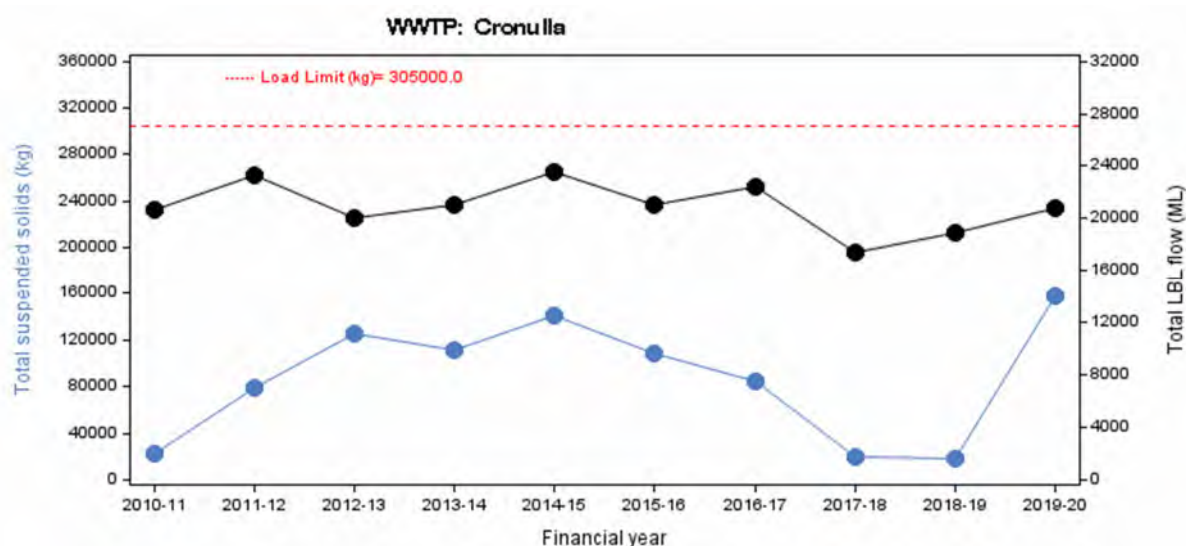
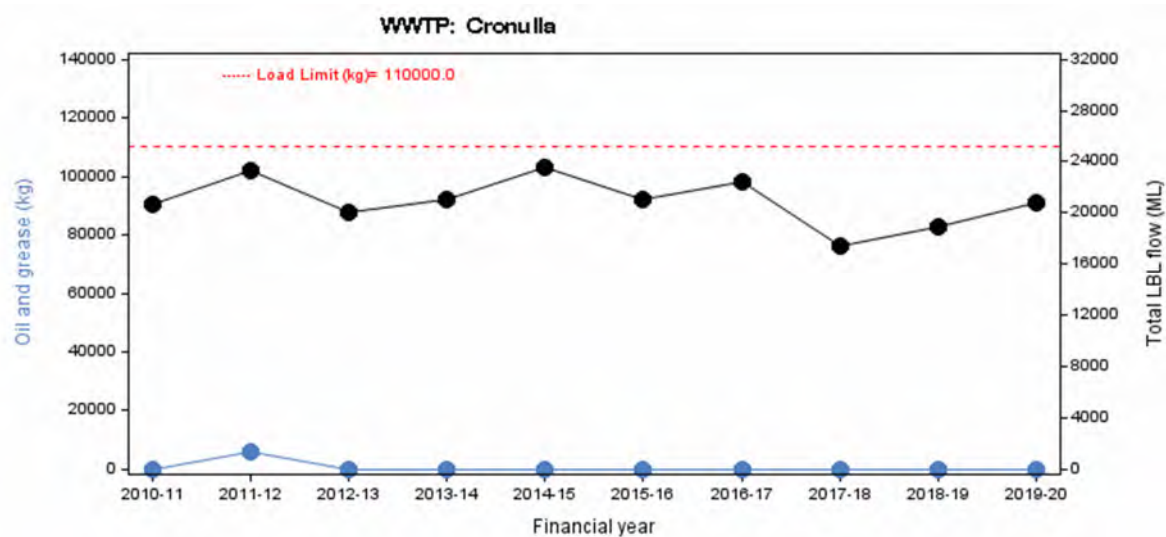
Note: 2019-20 data was compared with previous three years data (2016-2019) due to lab method change in 2016-17. Statistical test was not conducted because >90% of results were below the detection limit.



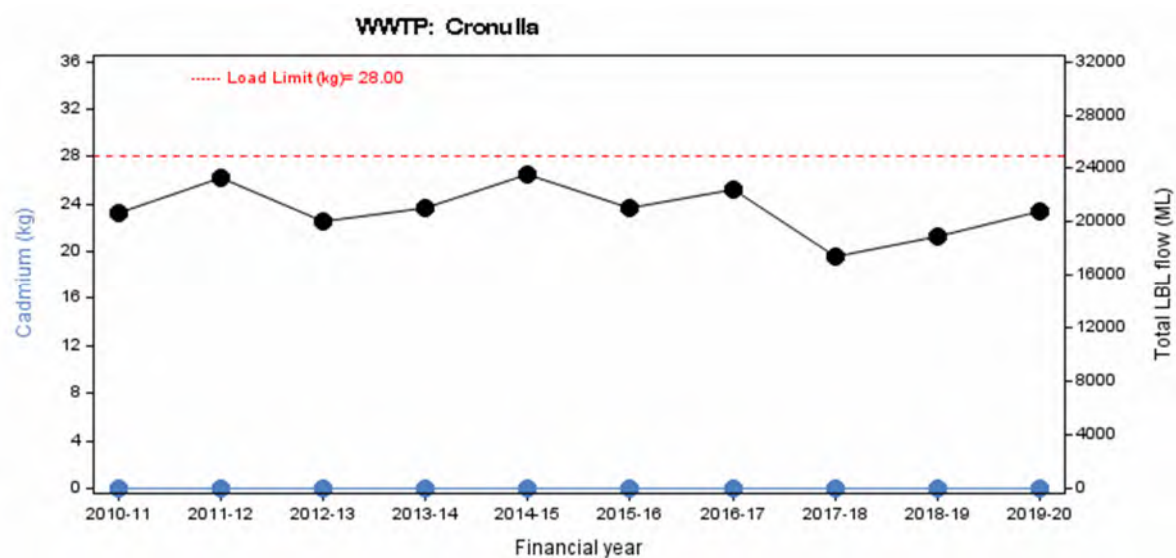


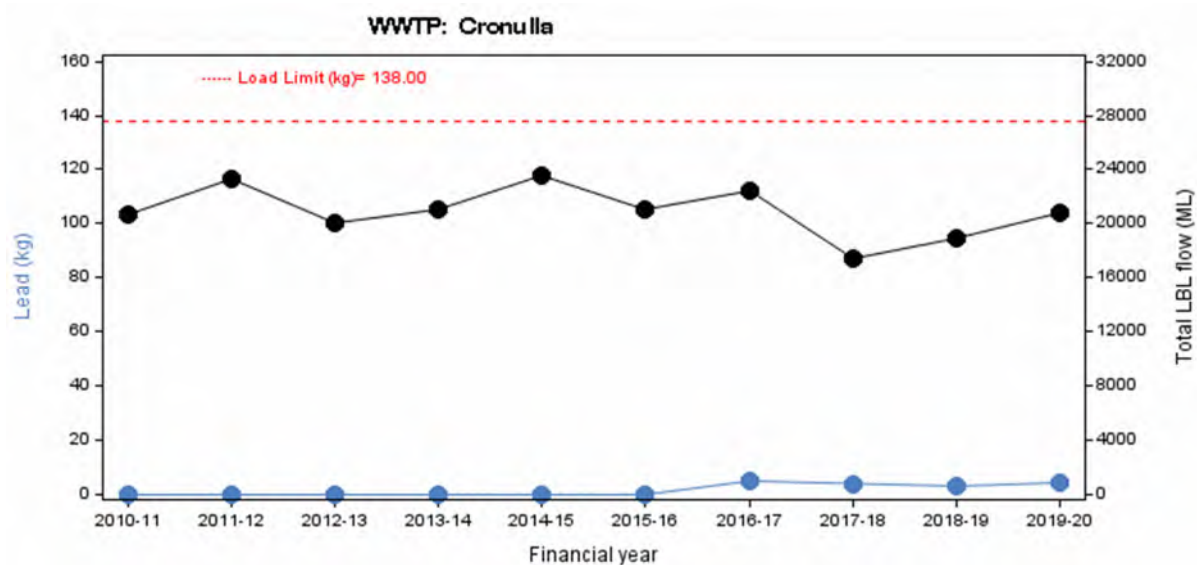
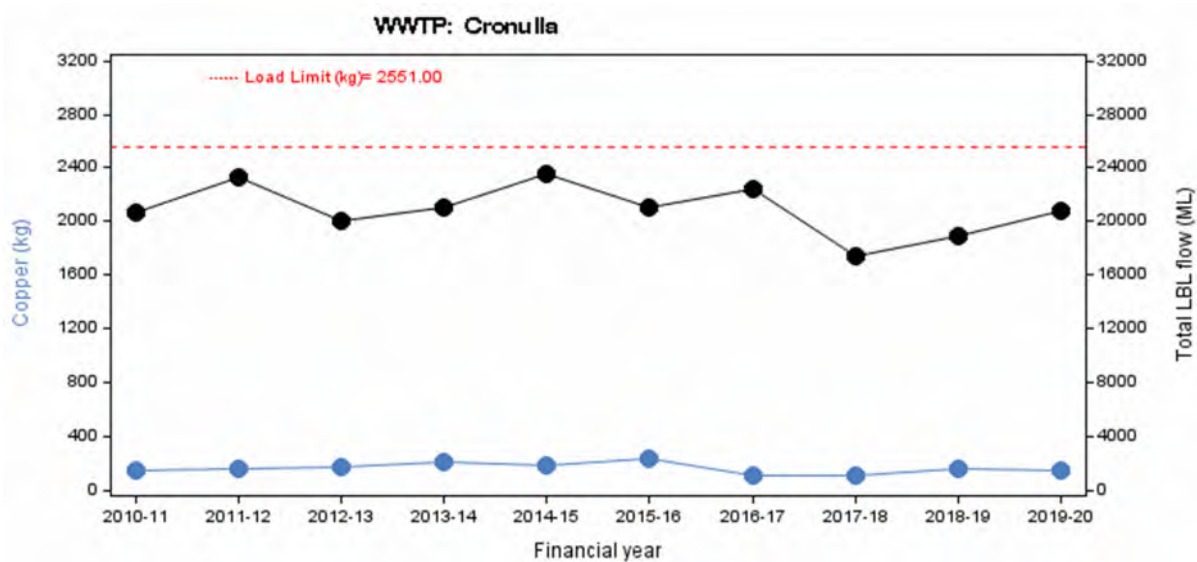
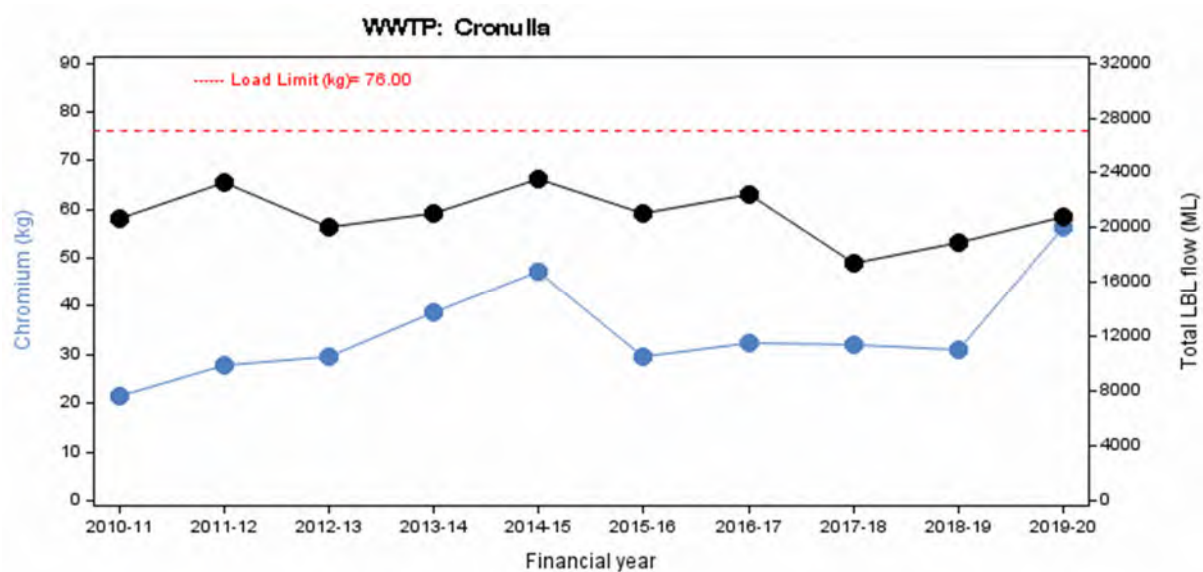
Discharge load: Major conventional analytes

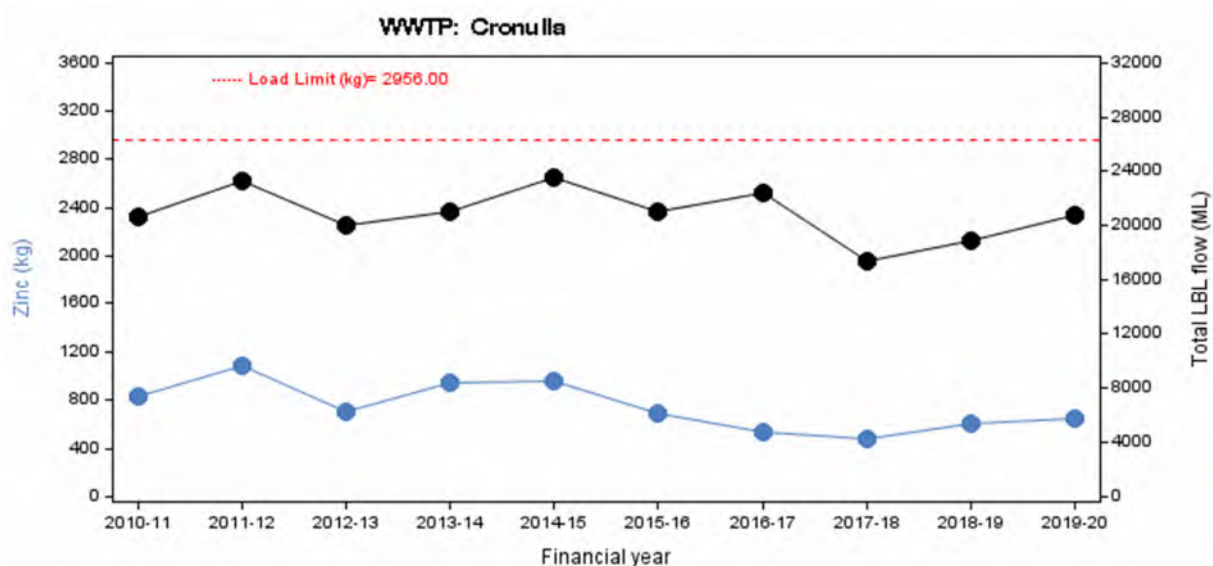
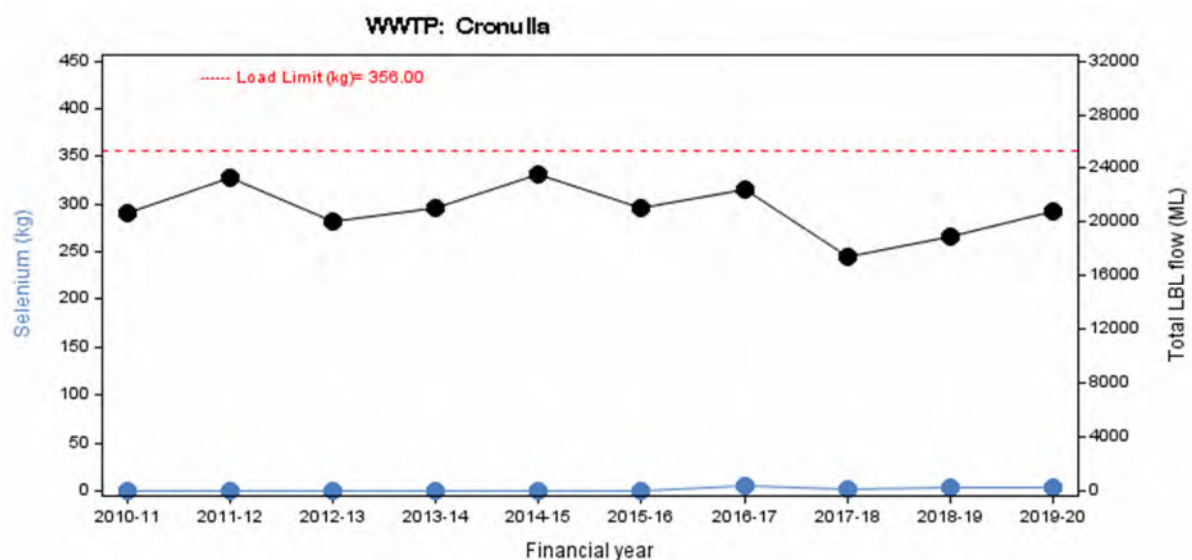
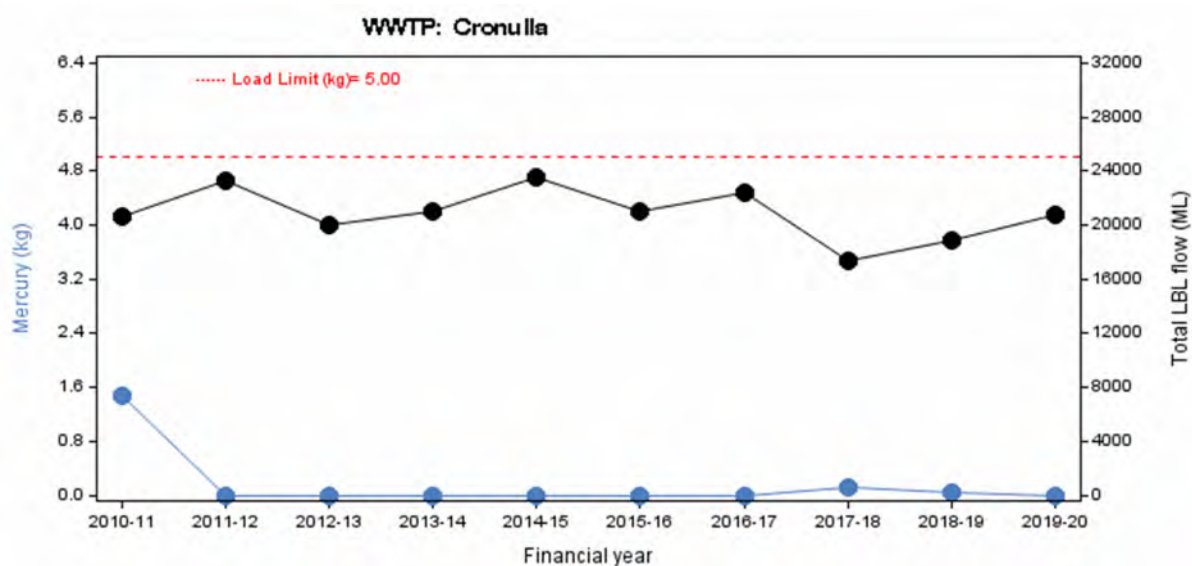




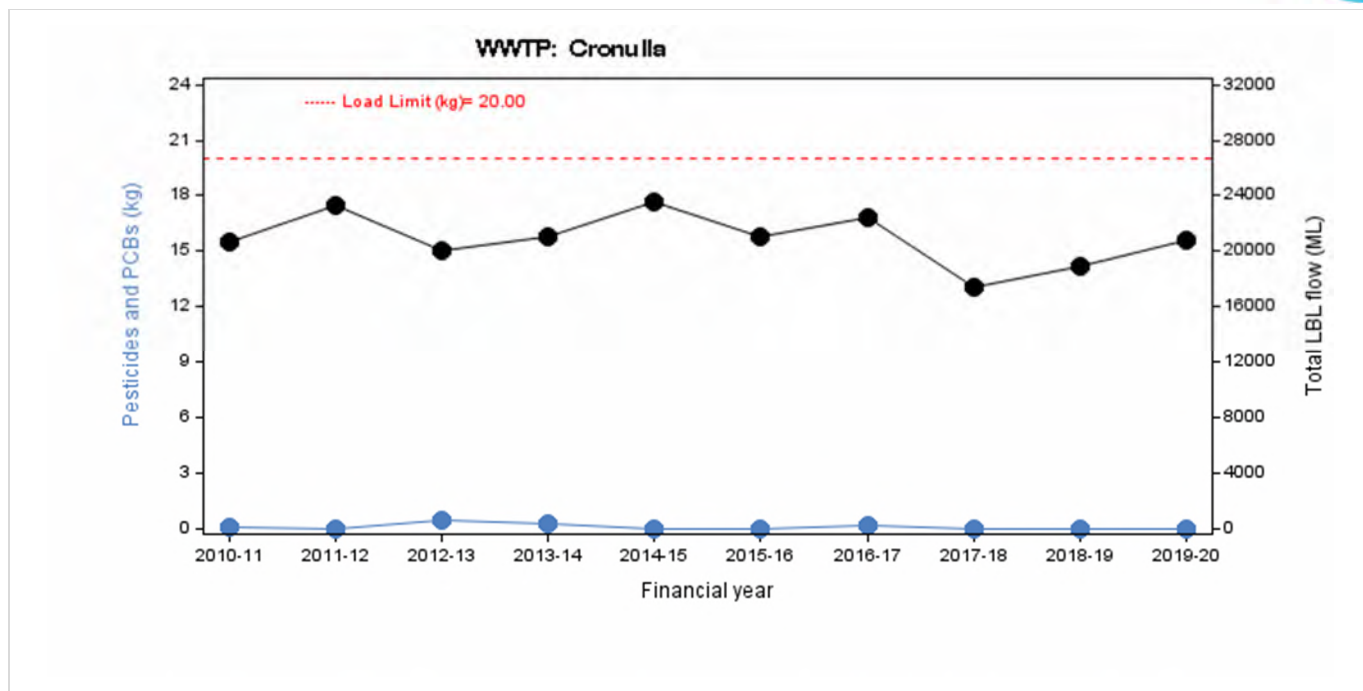
Discharge load: Trace Metals





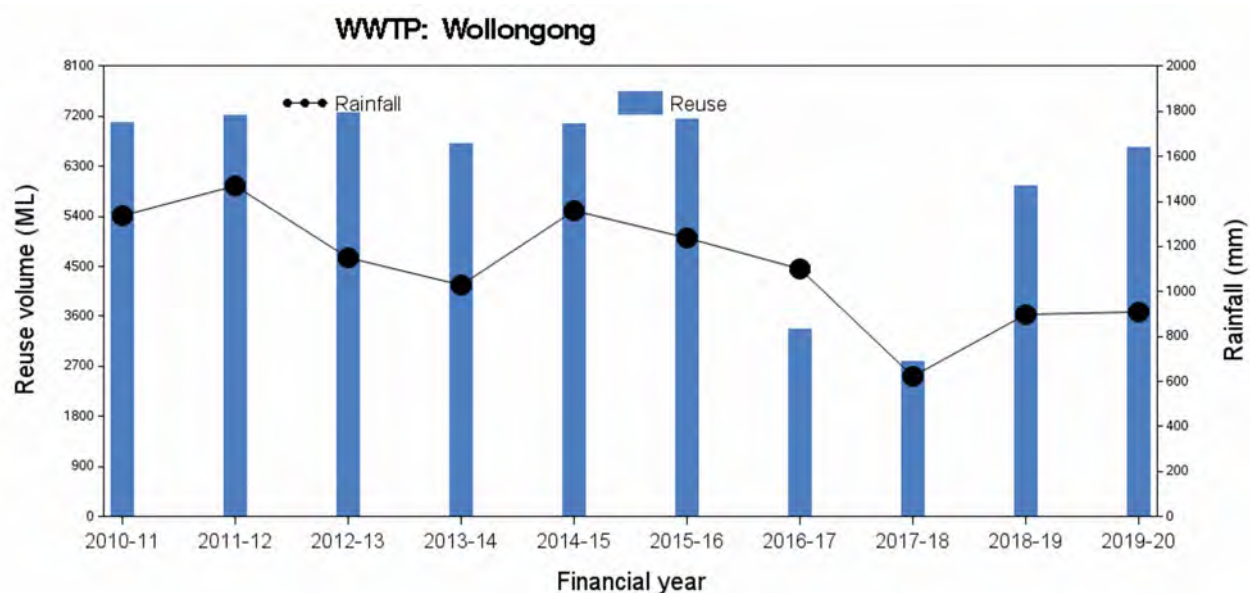
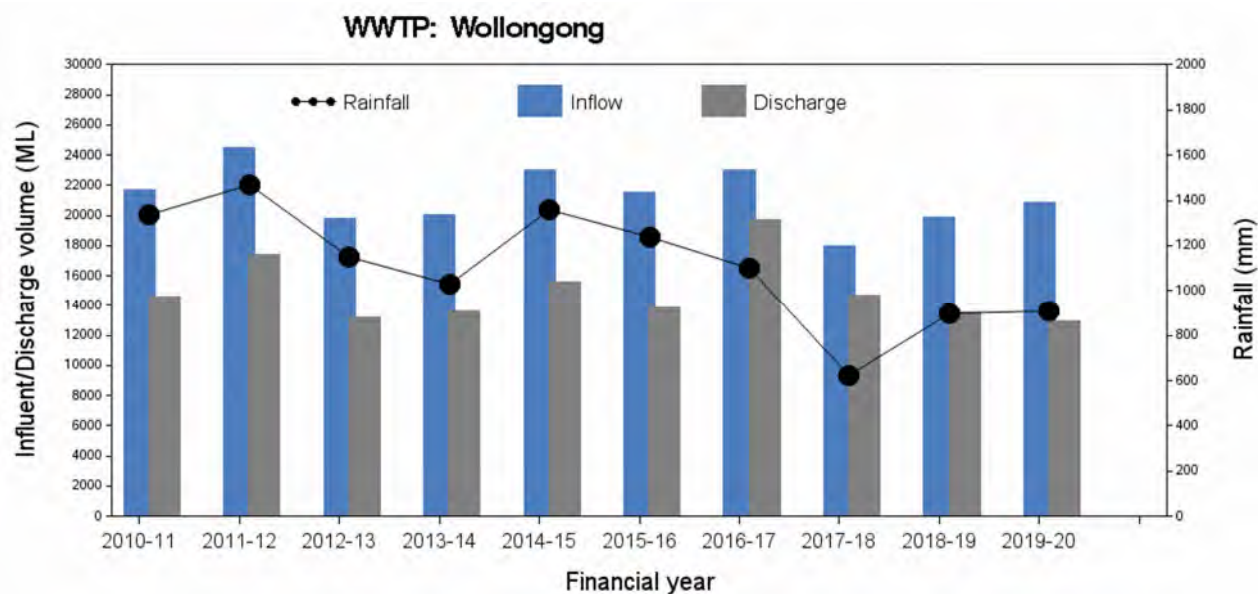


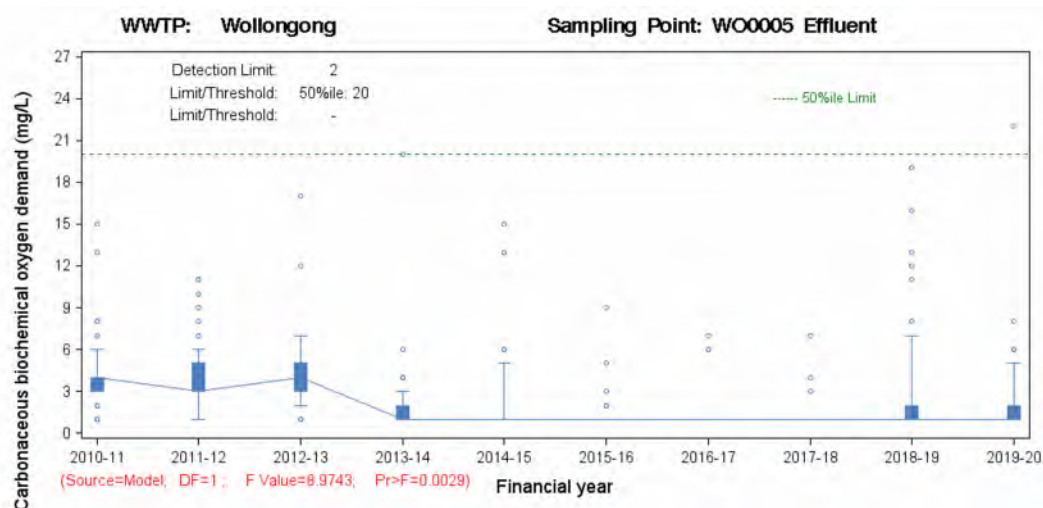
Discharge load: Other chemicals and organics (including pesticides)



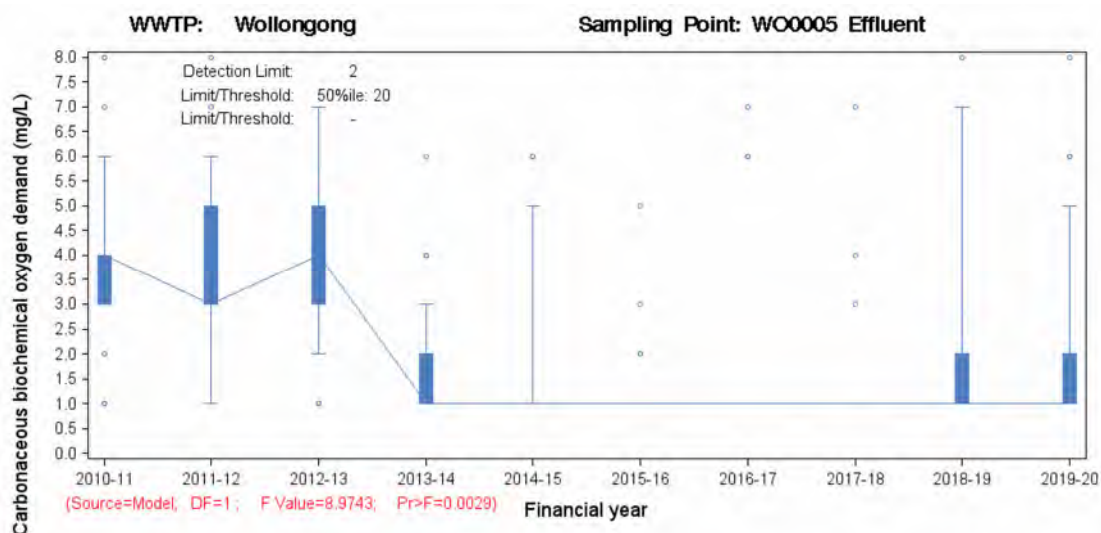
Wollongong WWTP

Discharge volume and rainfall

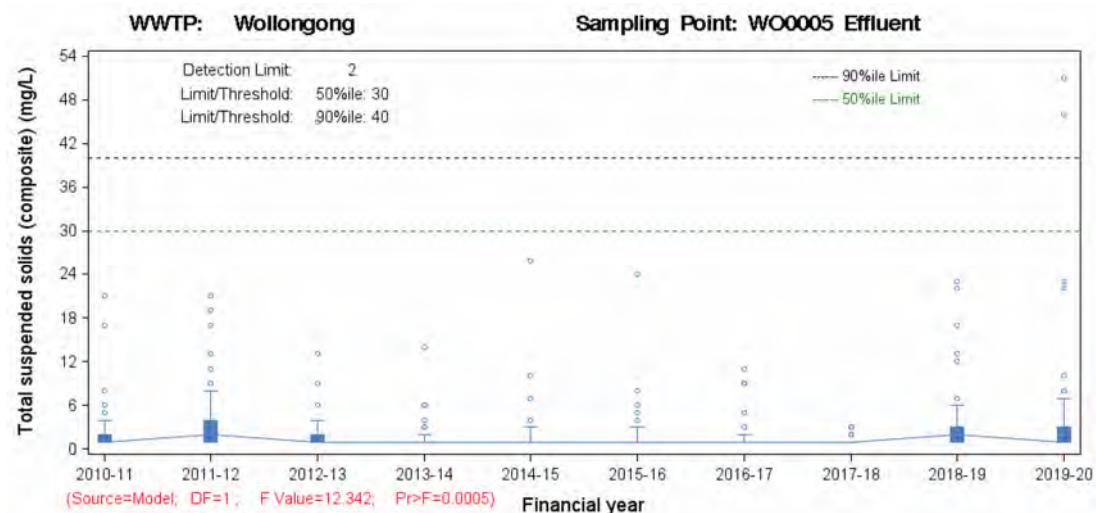


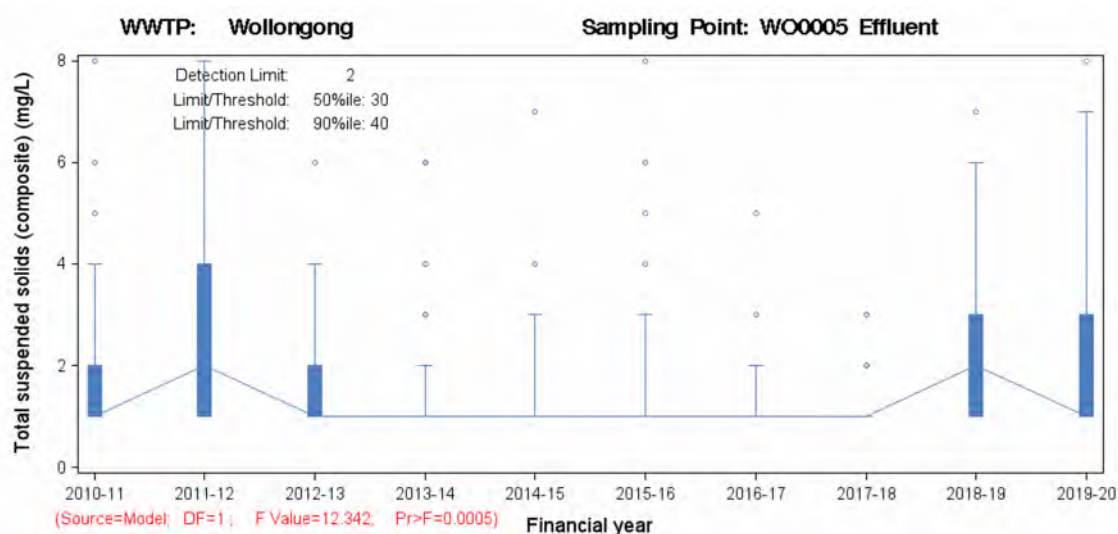


Note: Statistical test was based on 2019-20 data with previous five years data (2014-2019) due to lab method change in 2014-15.

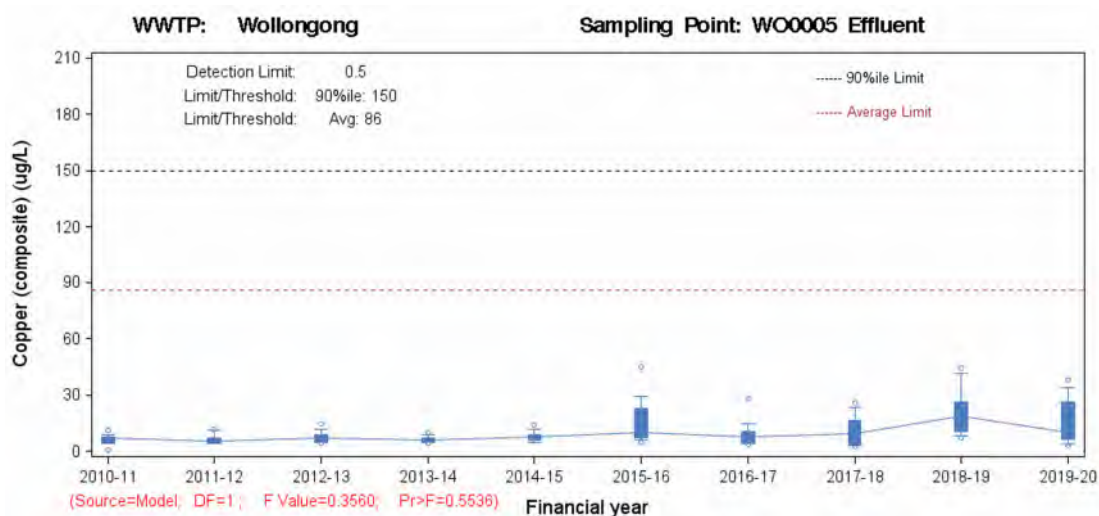
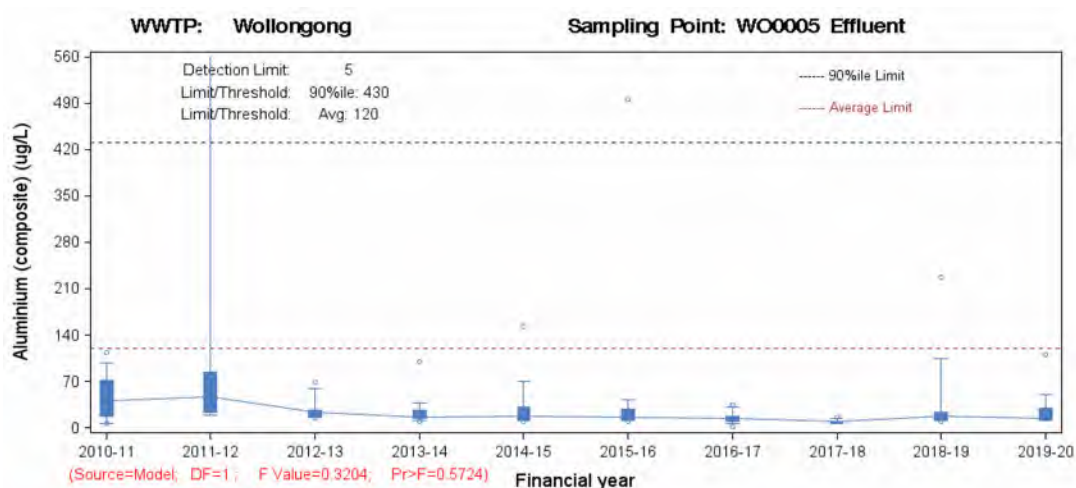


Note: Statistical test was based on 2019-20 data with previous five years data (2014-2019) due to lab method change in 2014-15.

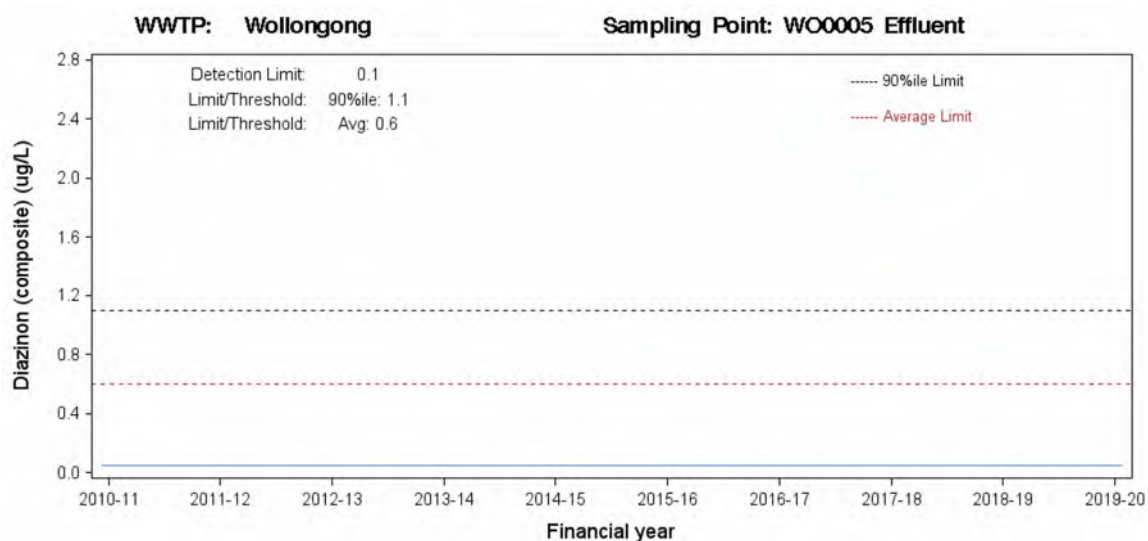




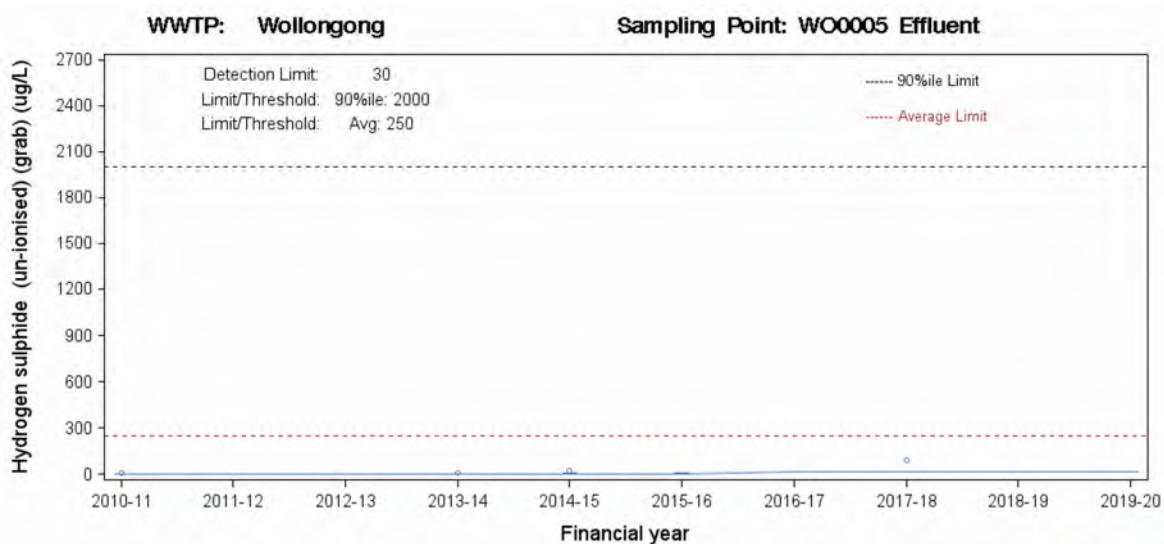
Discharge quality: Trace metals



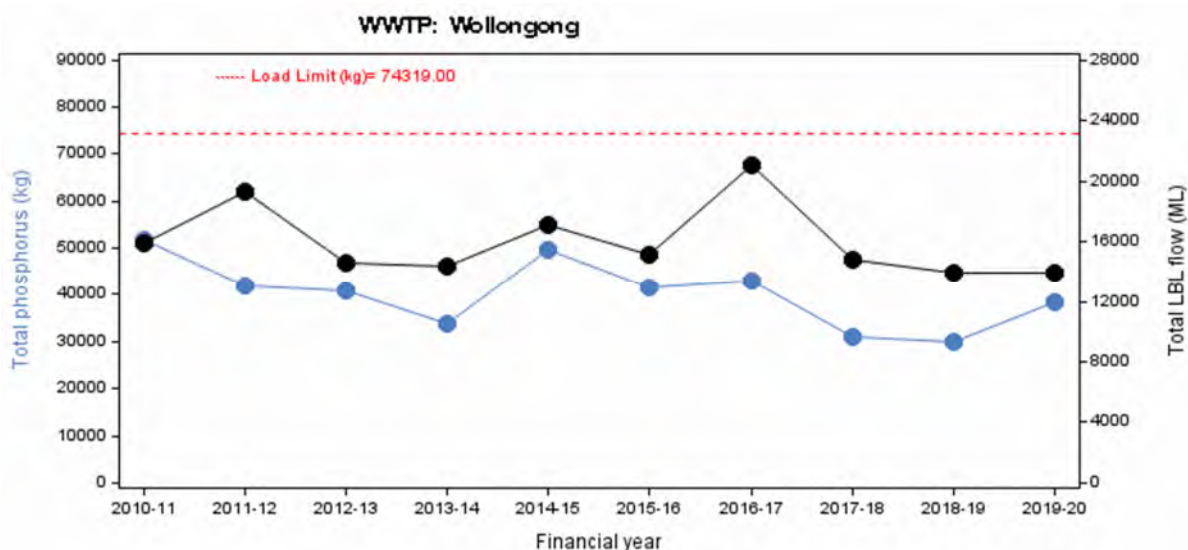
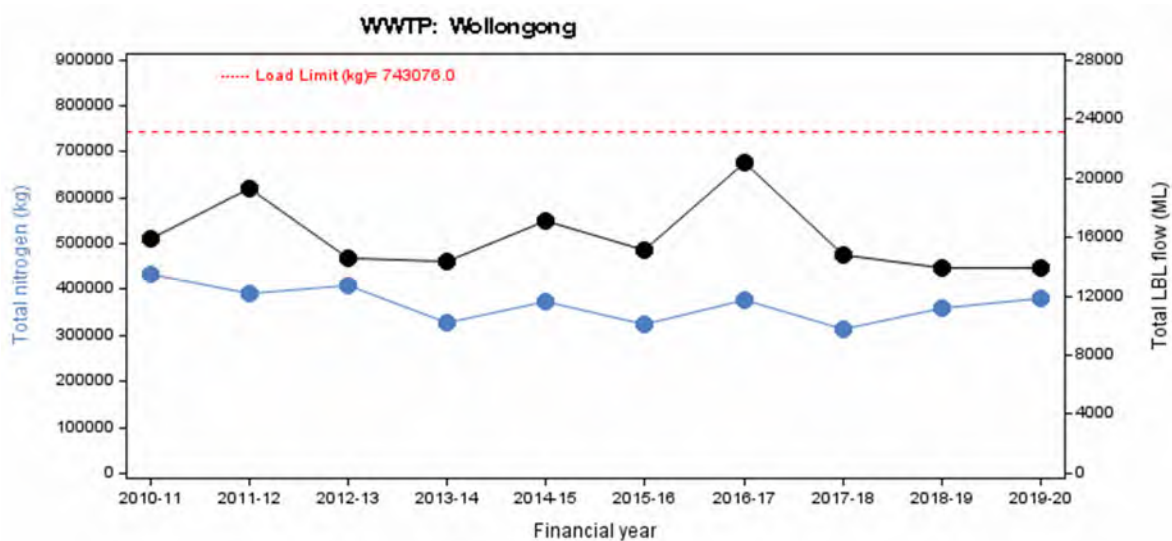
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.



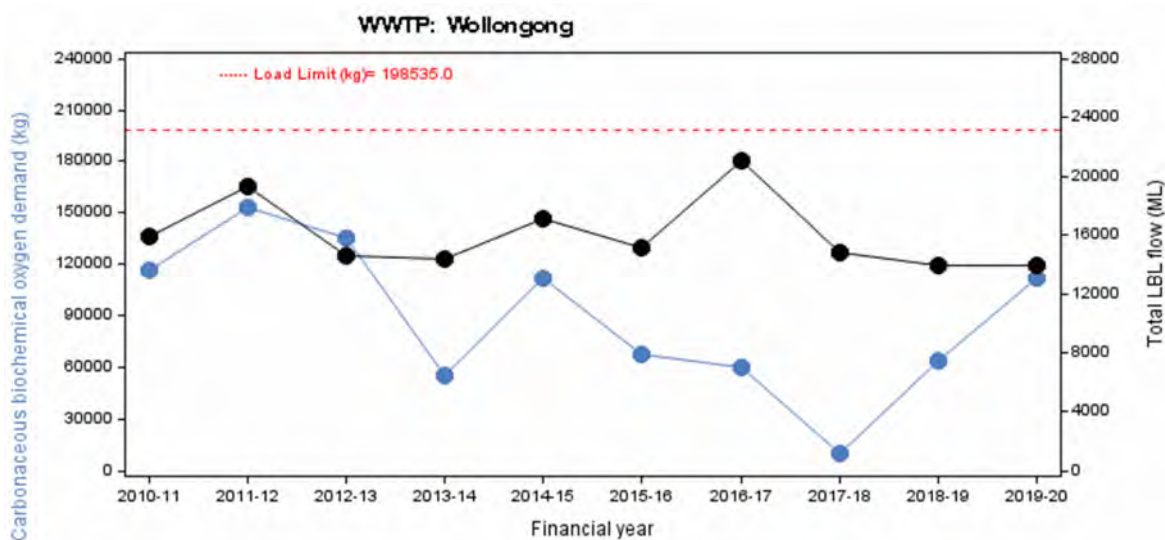
Note: Statistical test was not conducted because >90% of results were below the detection limit.

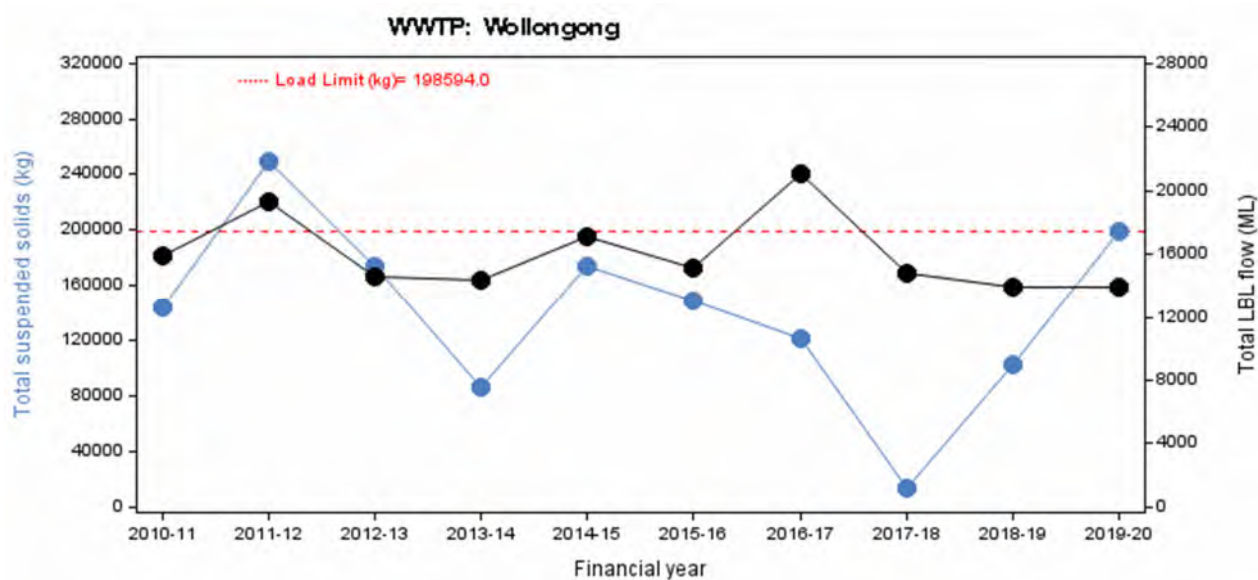
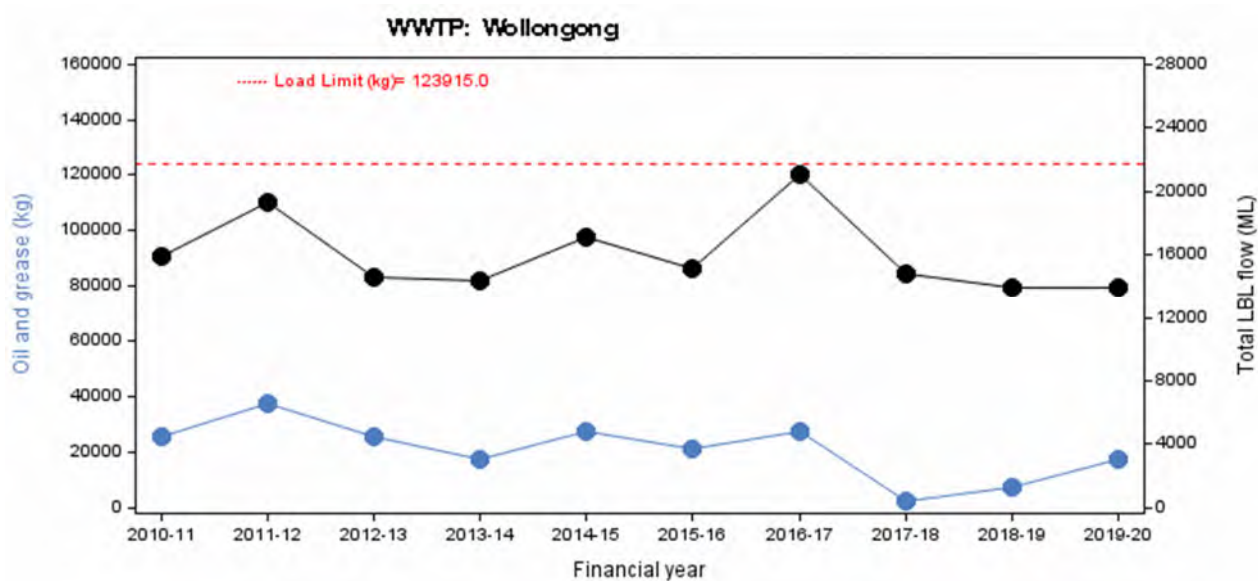


Note: 2019-20 data was compared with previous three years data (2016-2019) due to lab method change in 2016-17.
Statistical test was not conducted because >90% of results were below the detection limit.



Discharge load: Major conventional analytes

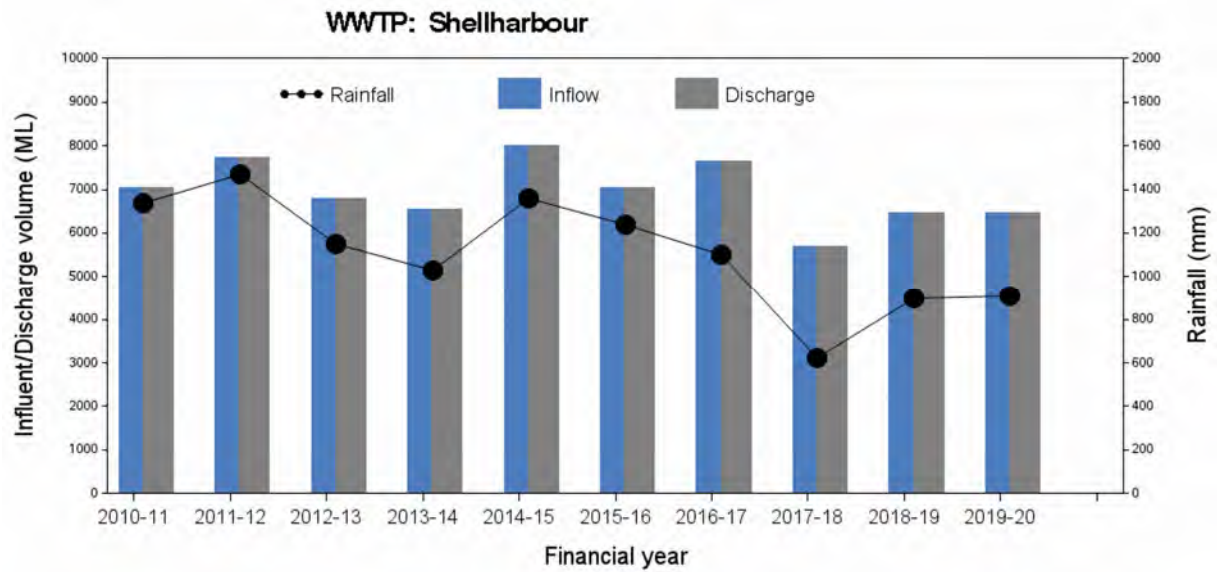




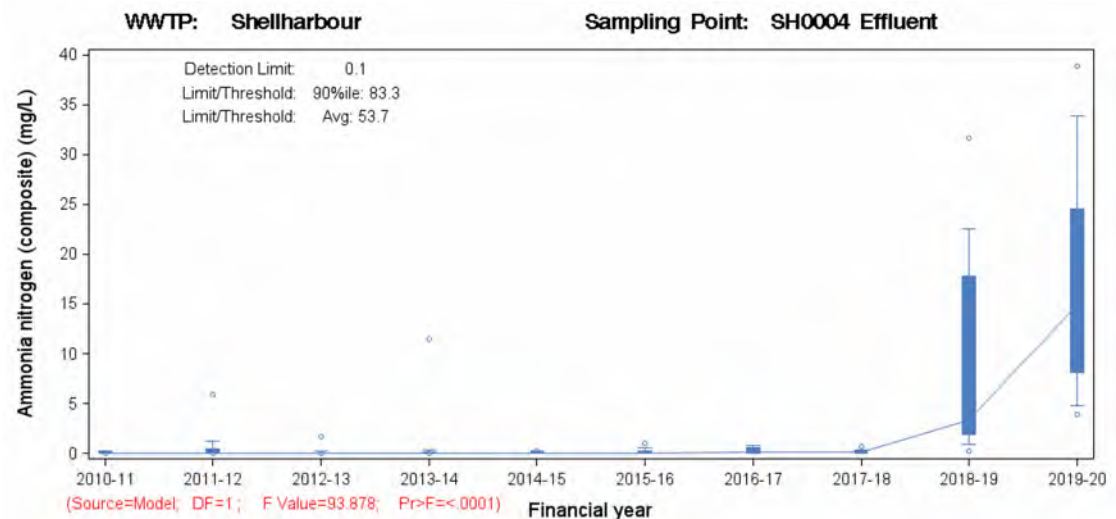
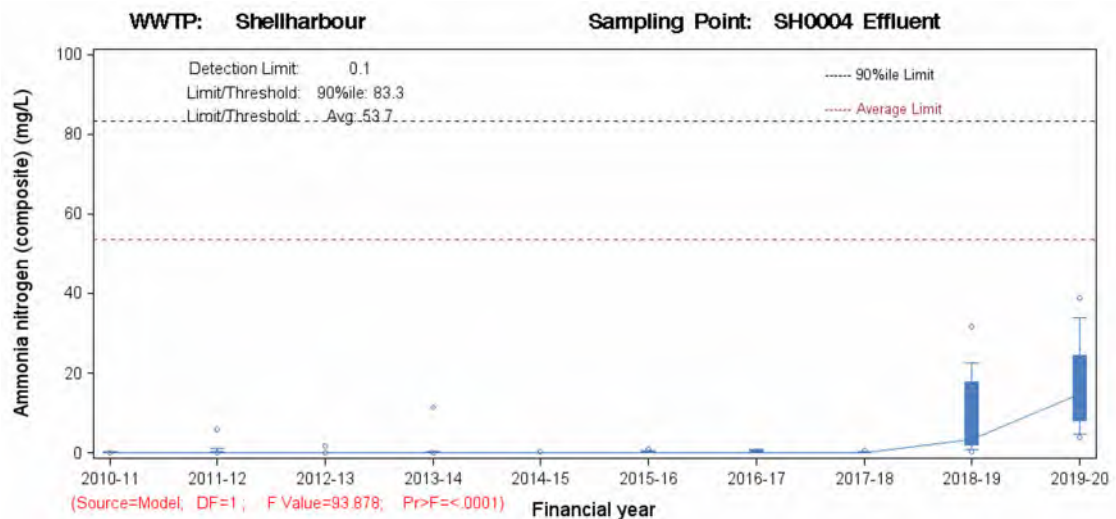
Note: Discharge loads at Wollongong WWTP also include discharges at Bellambi and Port Kembla WWTPs

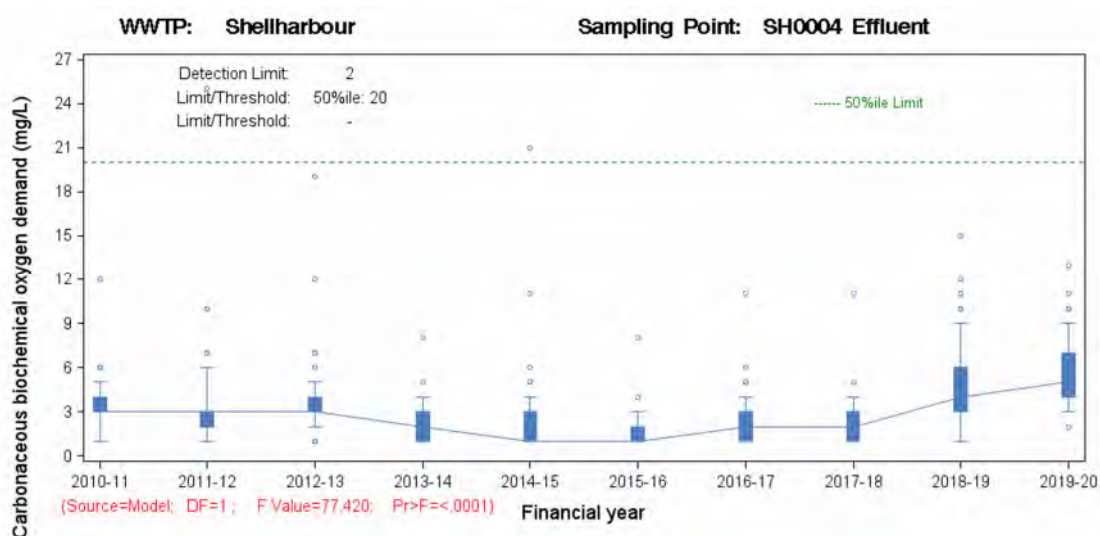
Shellharbour WWTP

Discharge volume and rainfall

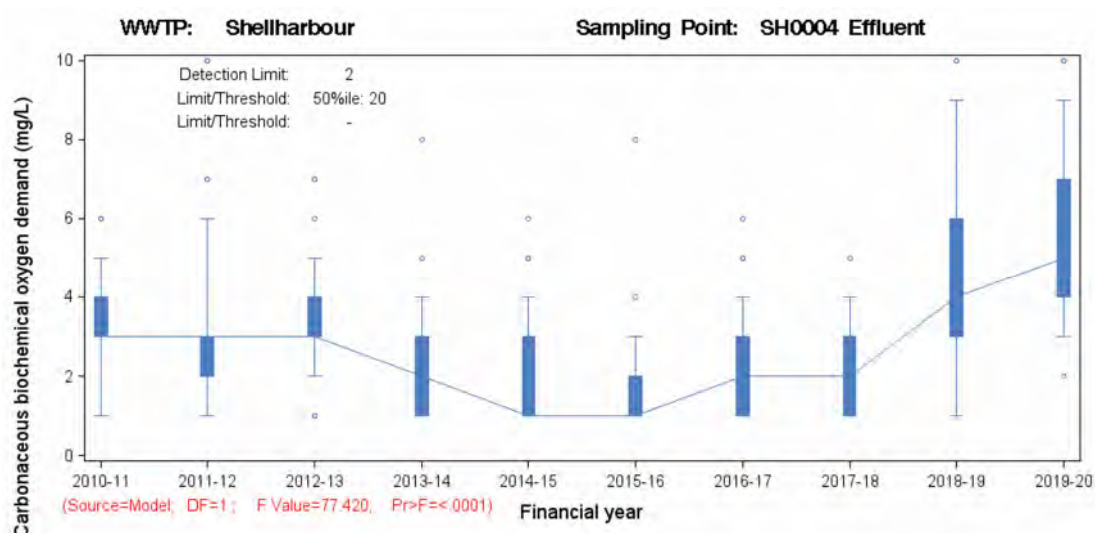


Discharge quality: Nutrients

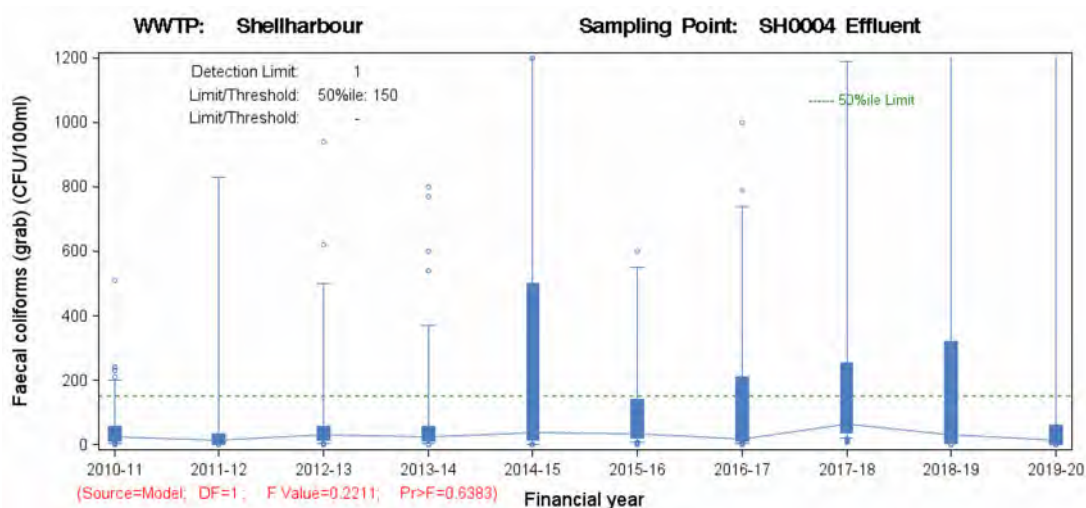


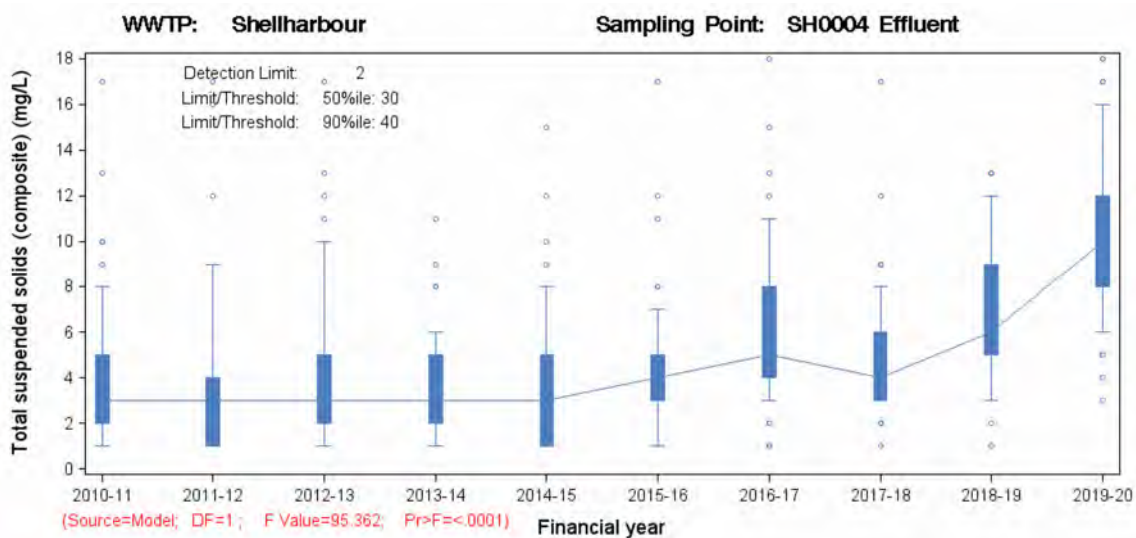
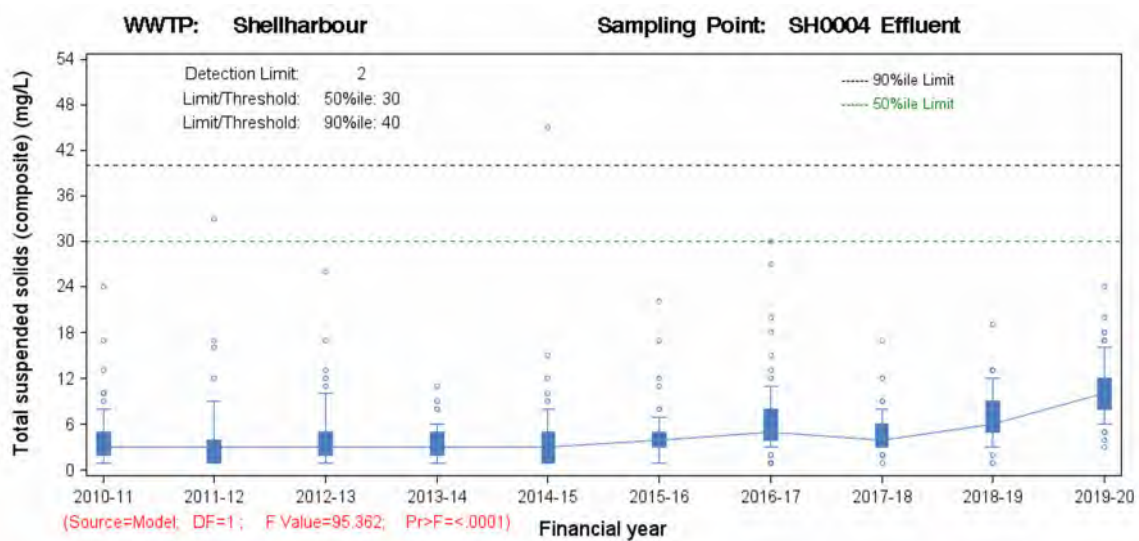


Note: Statistical test was based on 2019-20 data with previous five years data (2014-2019) due to lab method change in 2014-15.

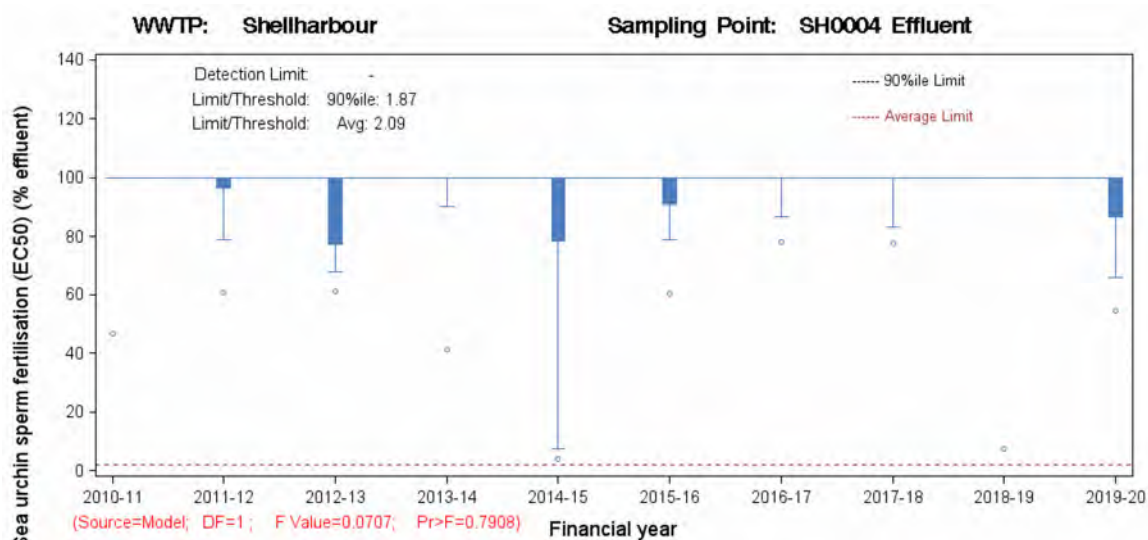


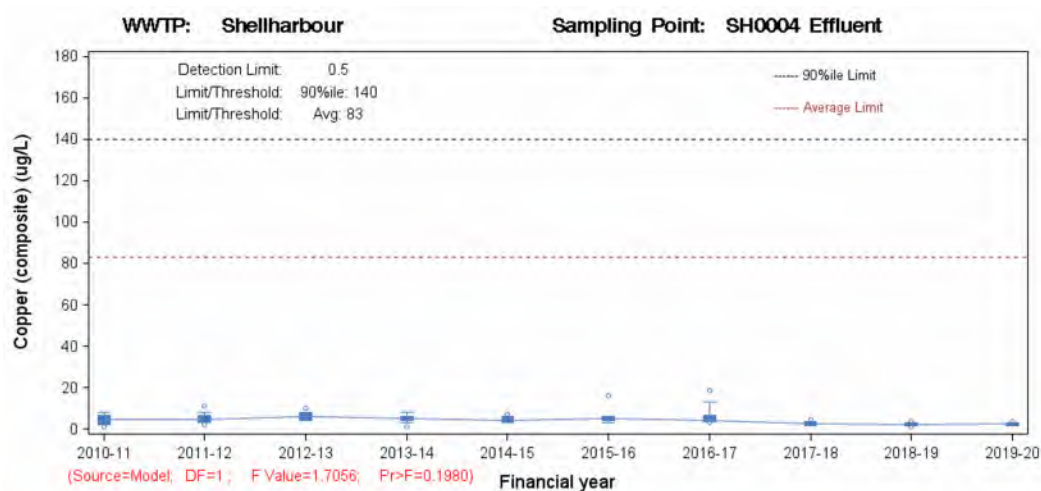
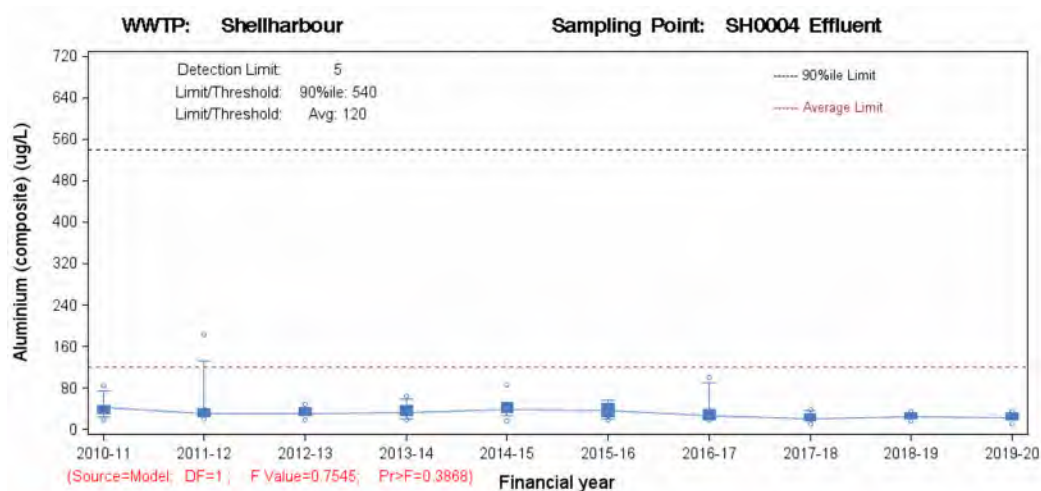
Note: Statistical test was based on 2019-20 data with previous five years data (2014-2019) due to lab method change in 2014-15.





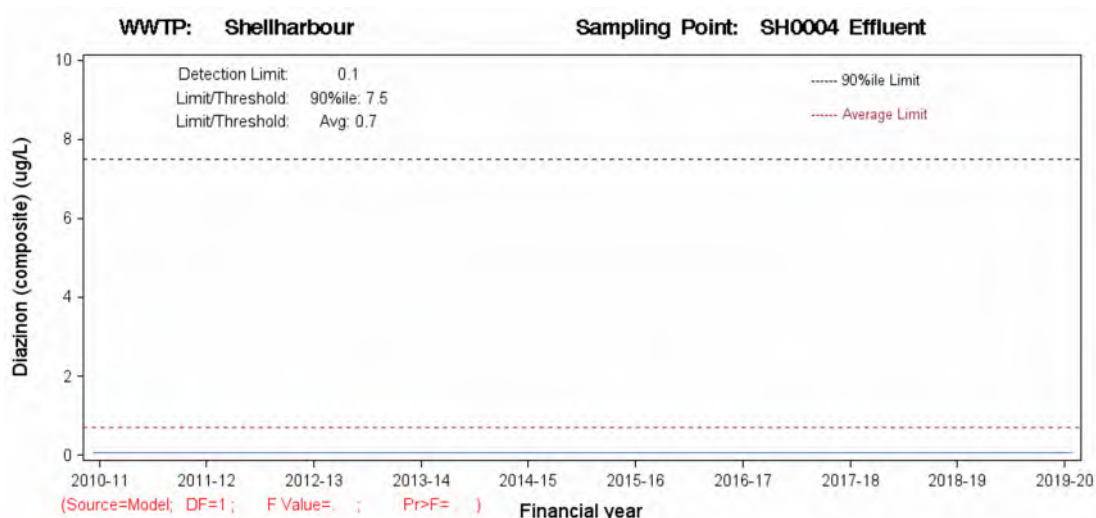
Discharge quality: Toxicity



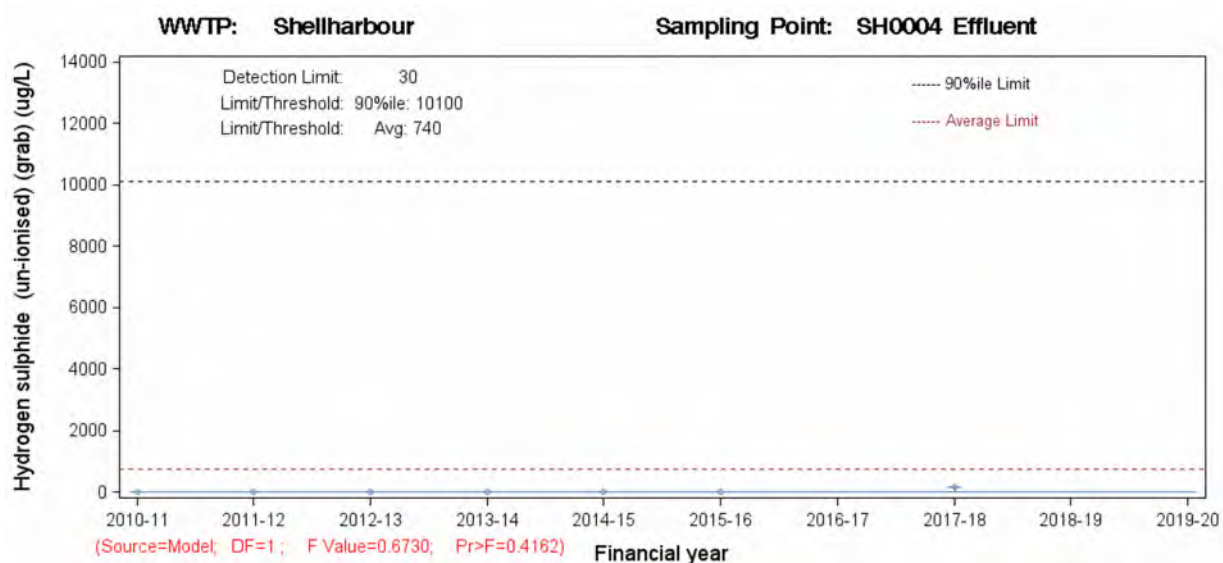


Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

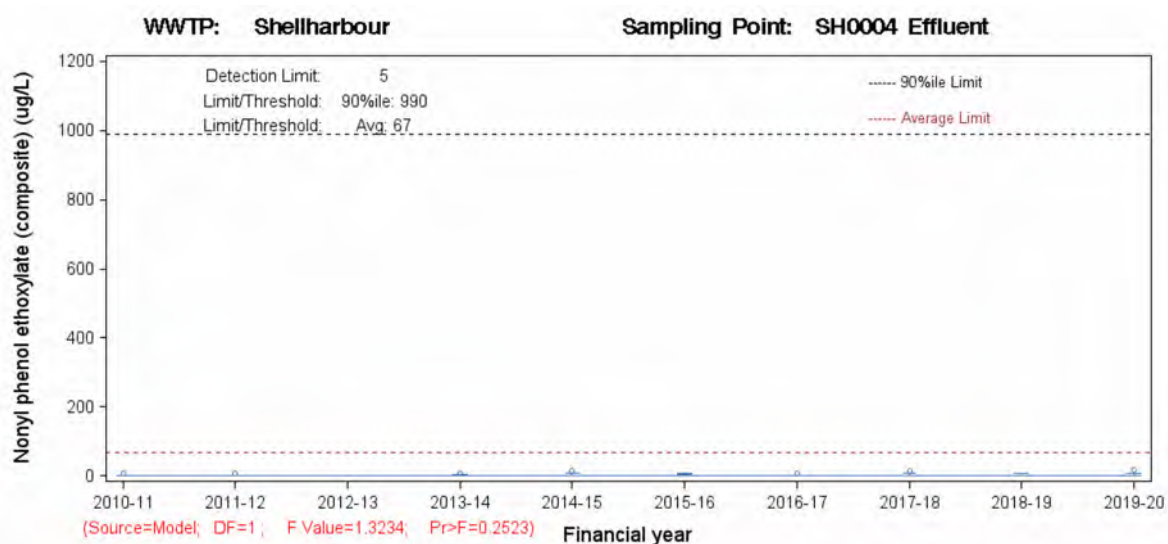
Discharge quality: Other chemicals and organics (including pesticides)

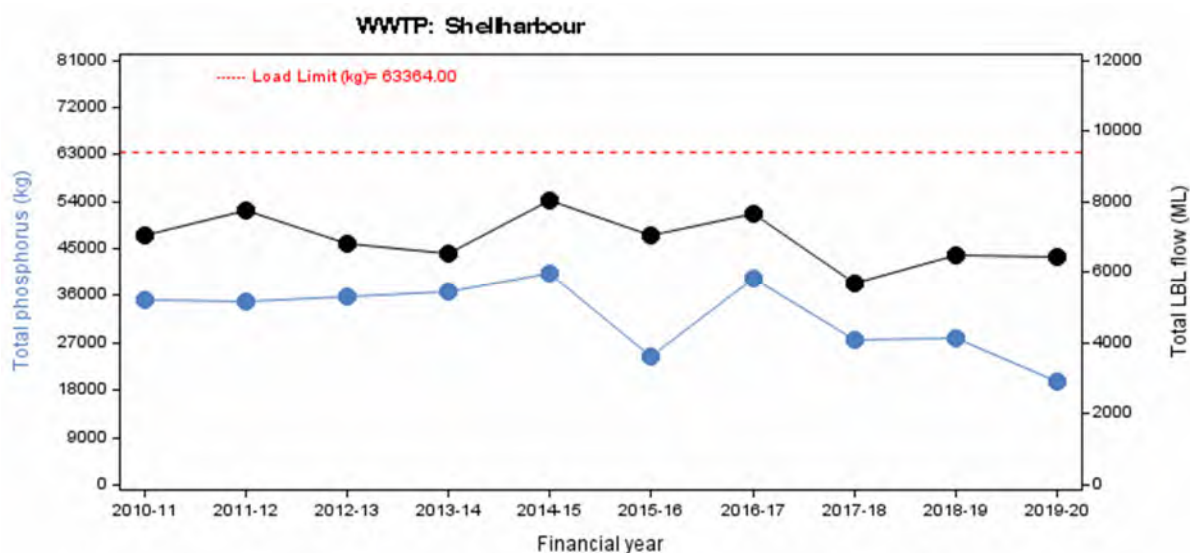
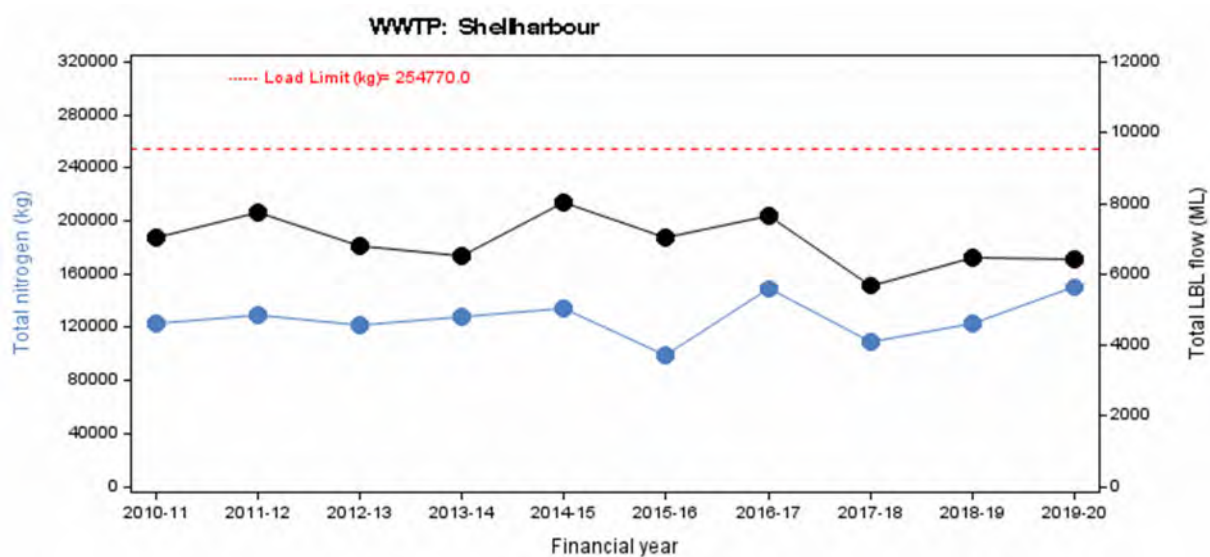


Note: Statistical test was not conducted because >90% of results were below the detection limit.

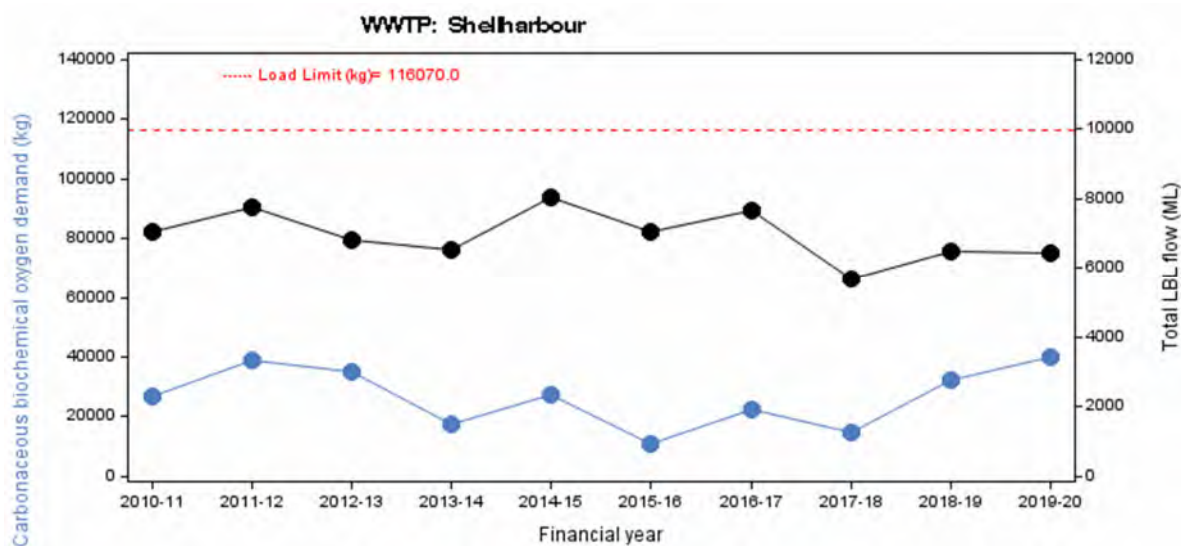


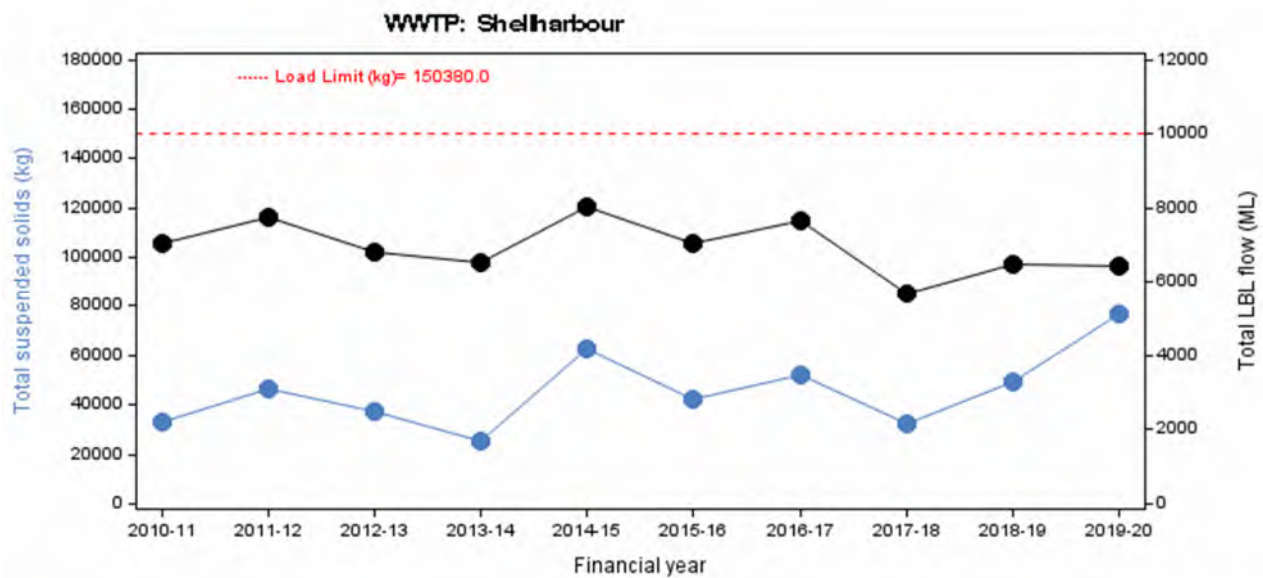
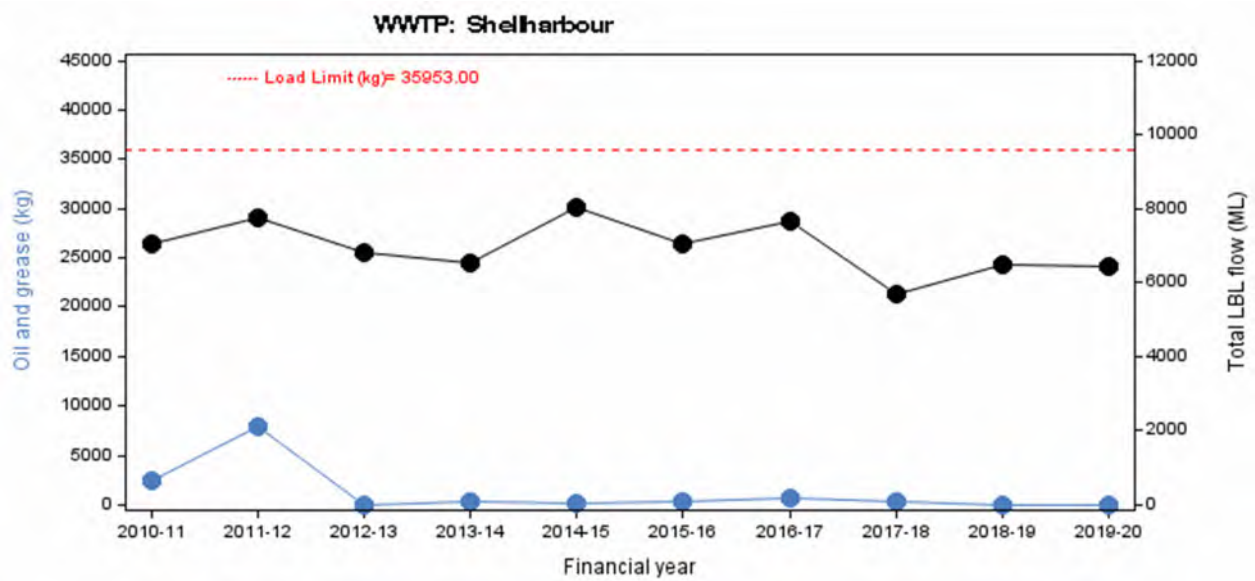
Note: There was a detection limit change in 2016-17. So, statistical test was based on 2019-20 data with previous three years data (2016-2018).





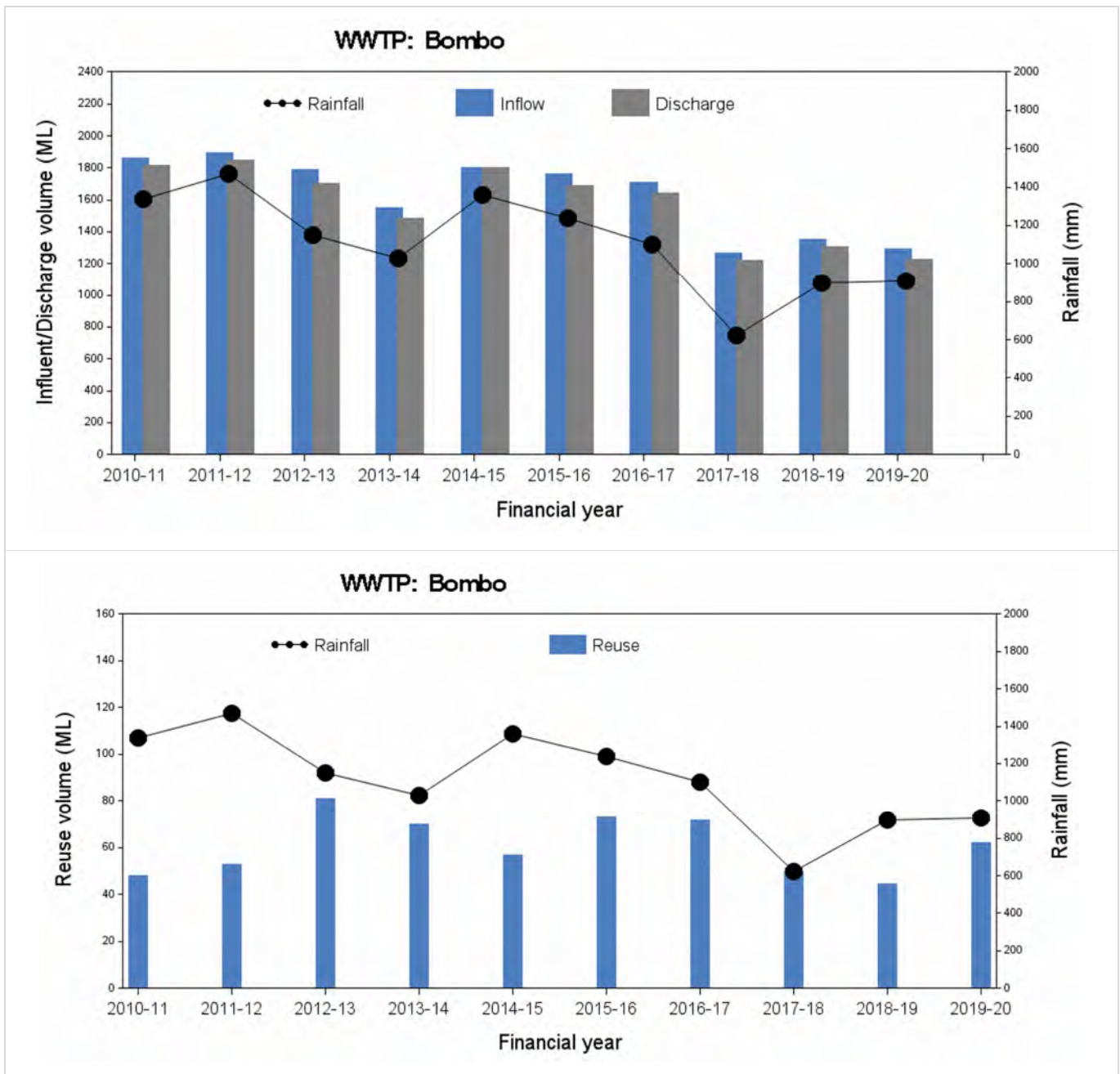
Discharge load: Major conventional analytes

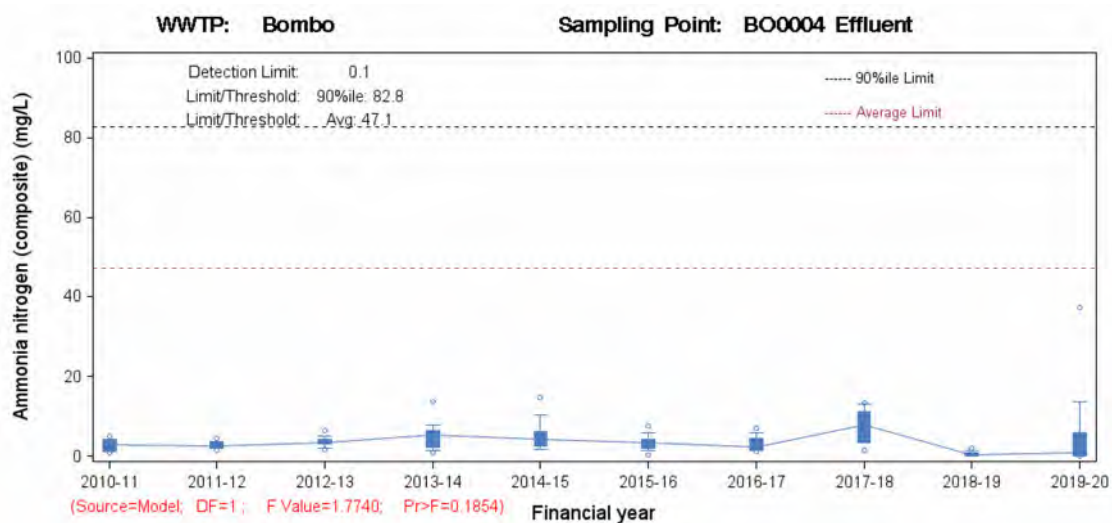




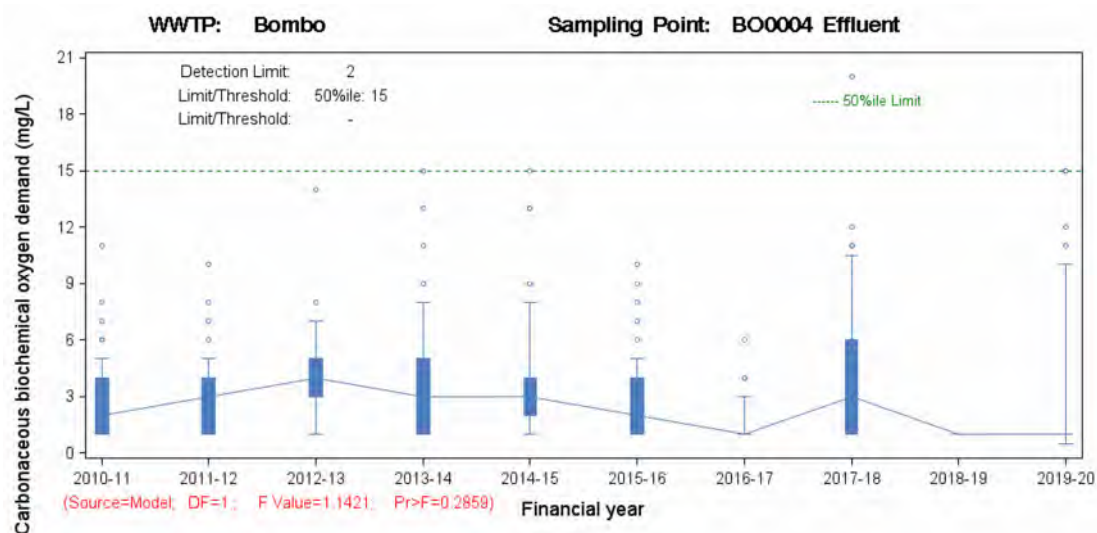
Bombo WWTP

Discharge volume and rainfall

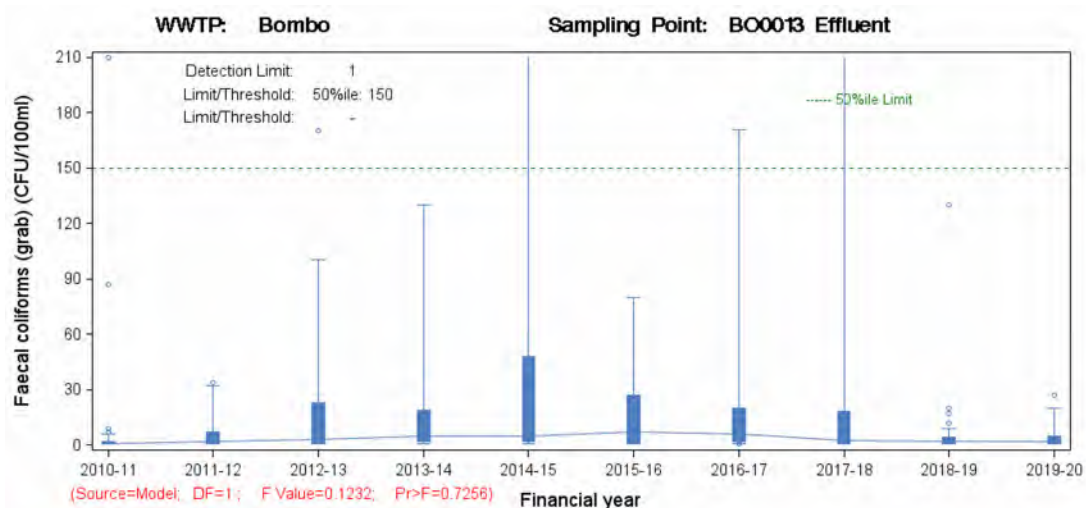


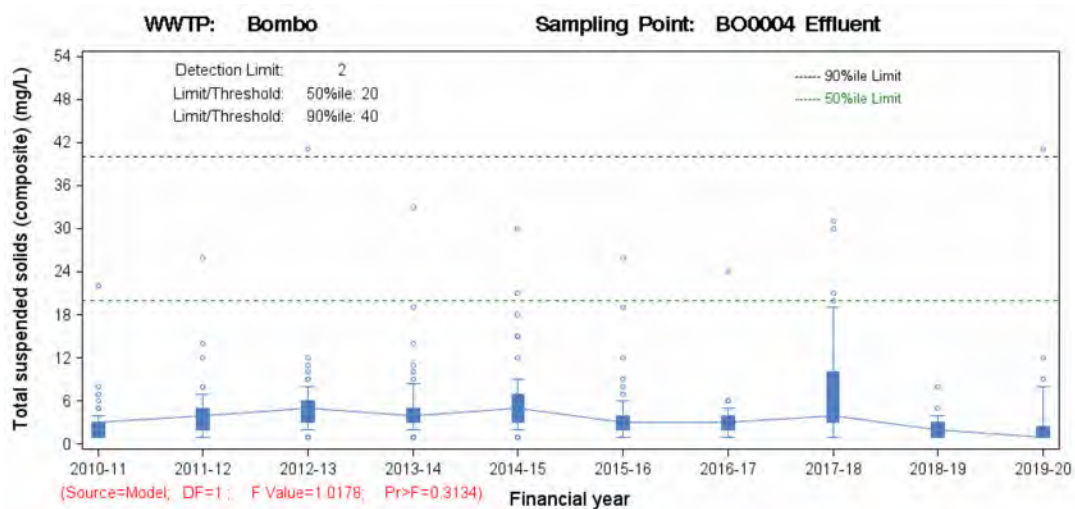


Discharge quality: Major conventional analytes

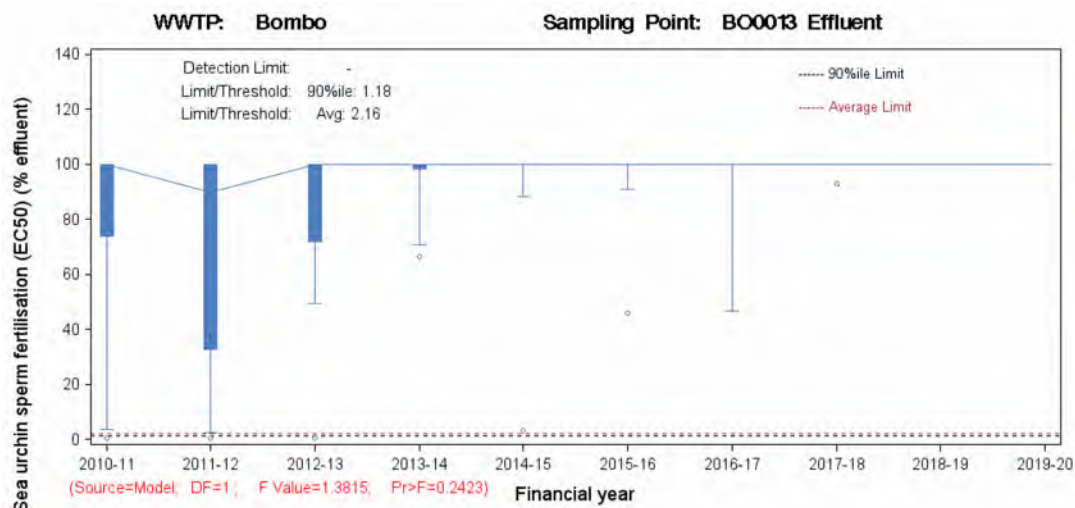


Note: Statistical test was based on 2019-20 data with previous five years data (2014-2019) due to lab method change in 2014-15.

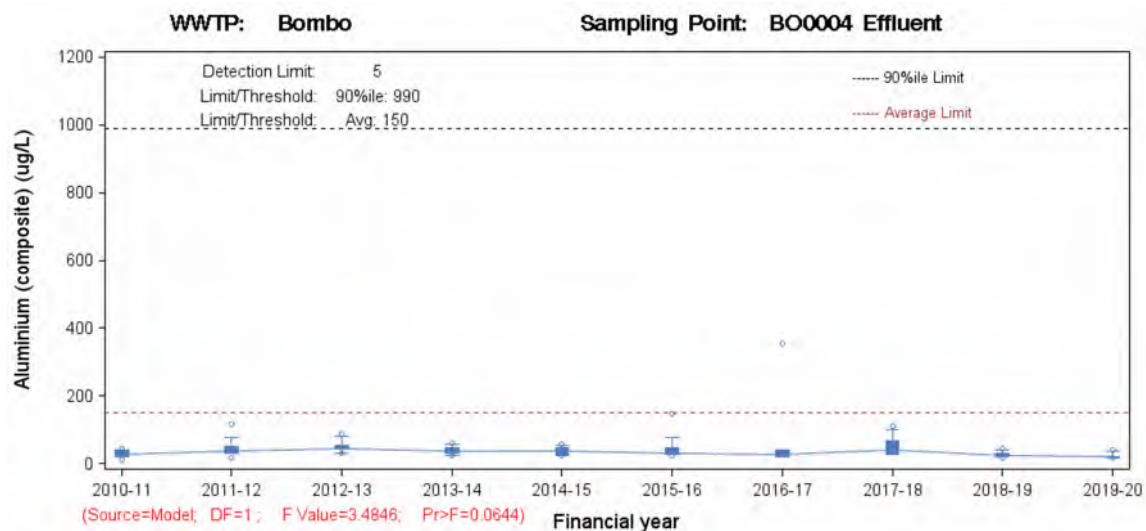


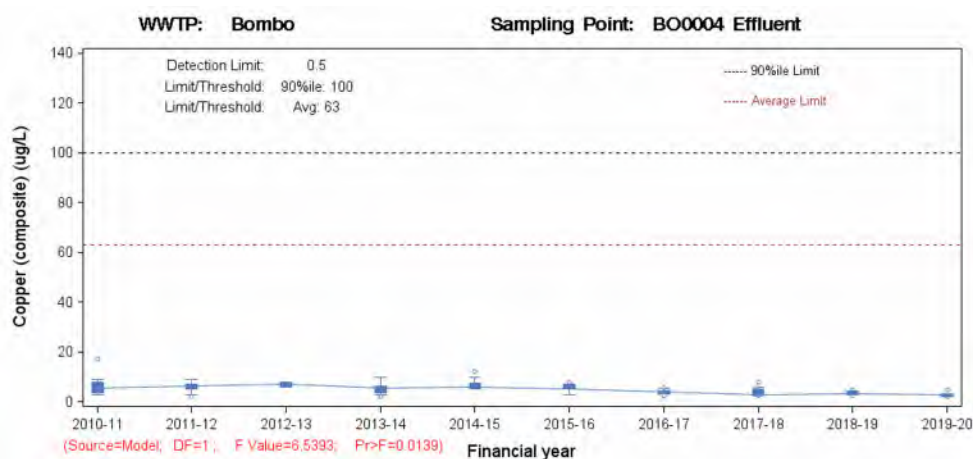


Discharge quality: Toxicity

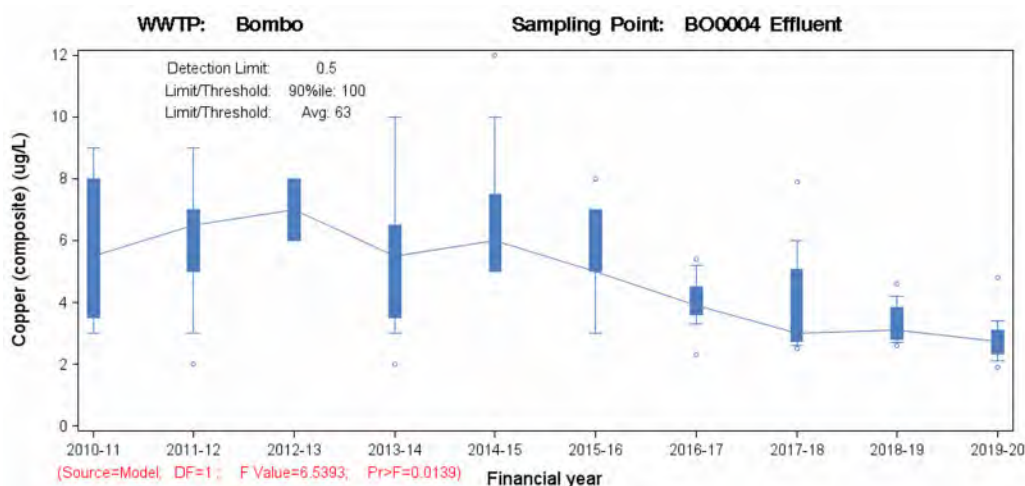


Discharge quality: Trace metals



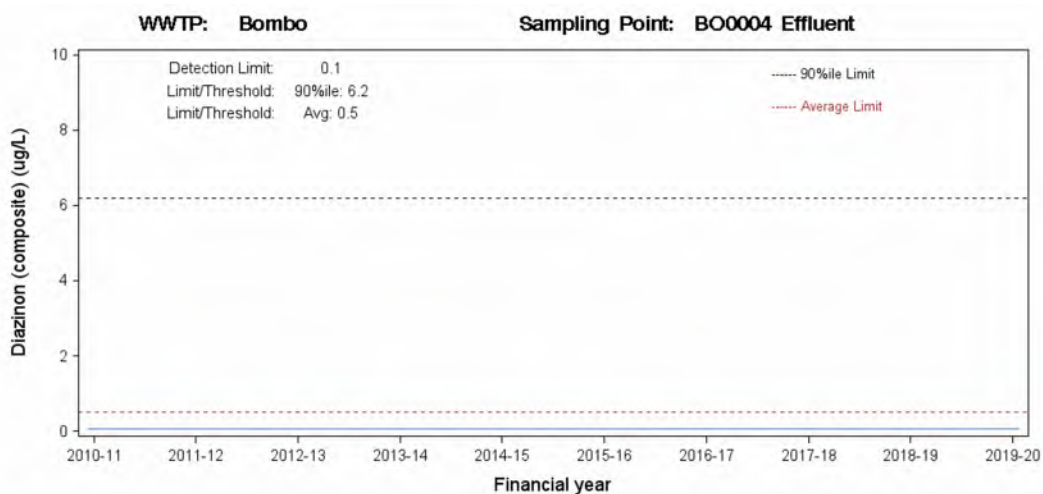


Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

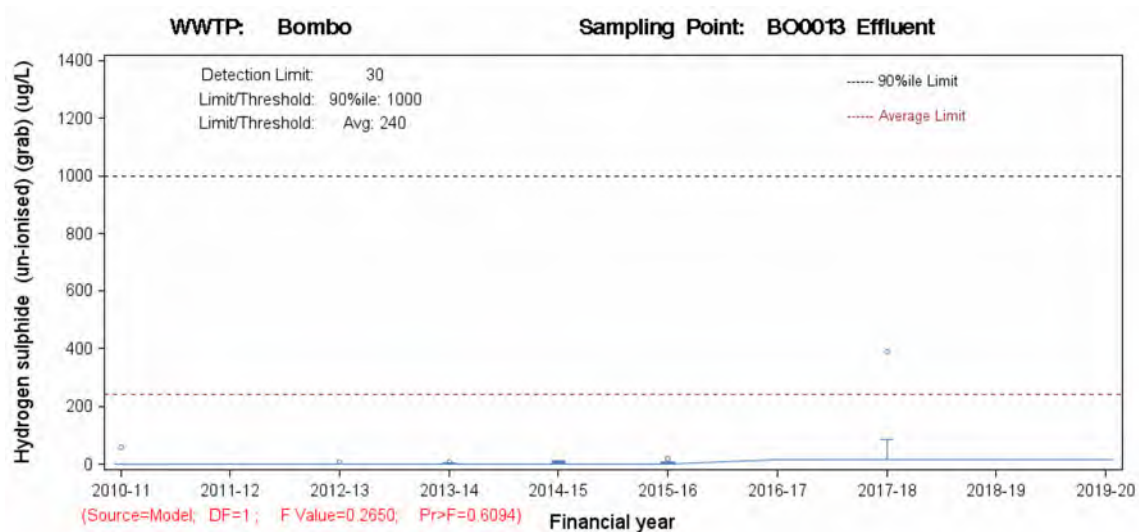


Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

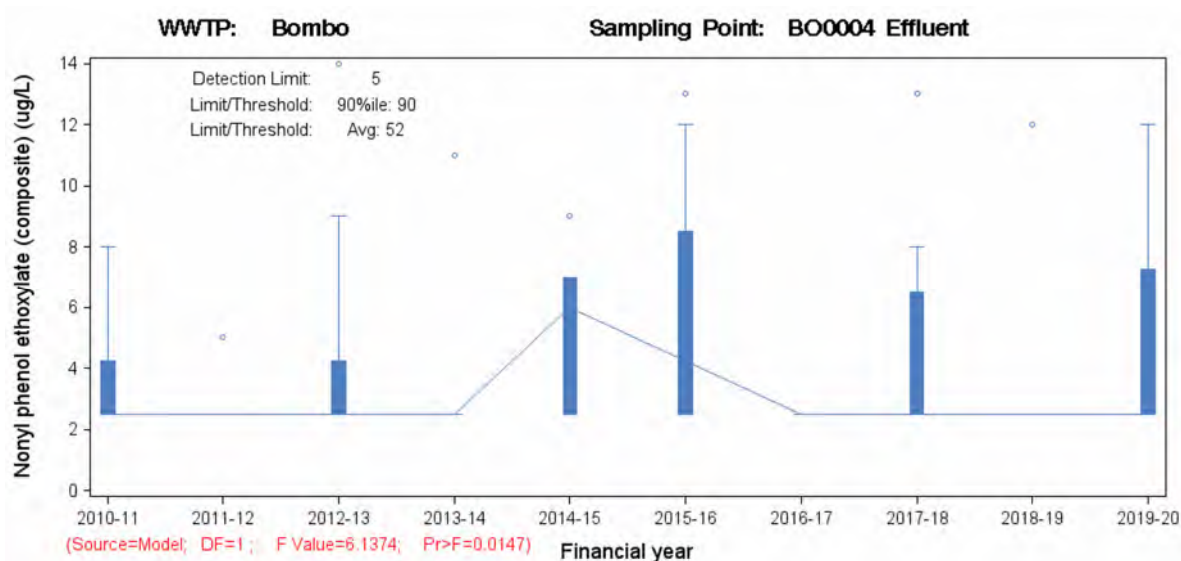
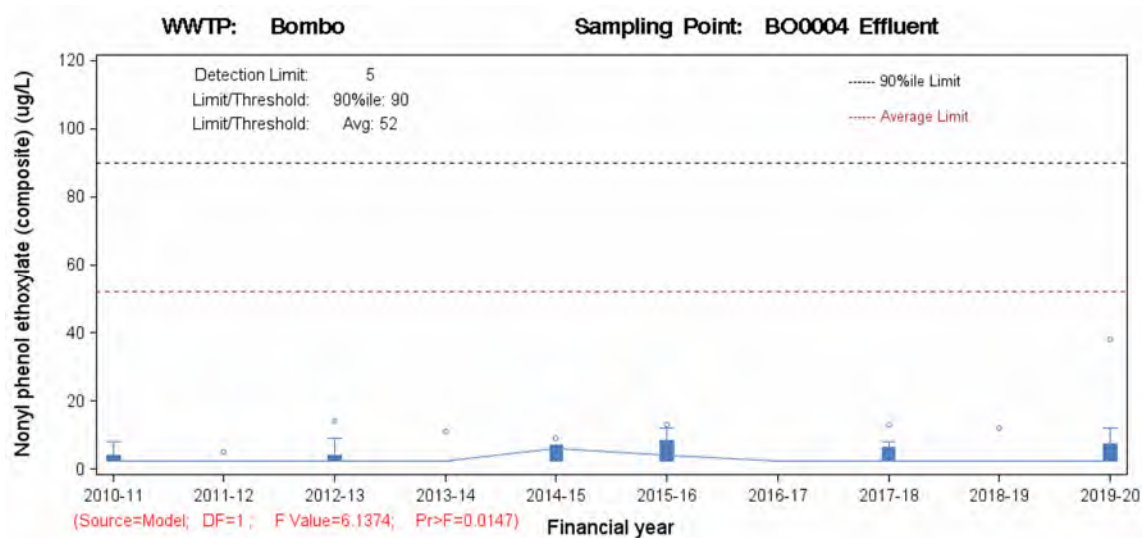
Discharge quality: Other chemicals and organics (including pesticides)

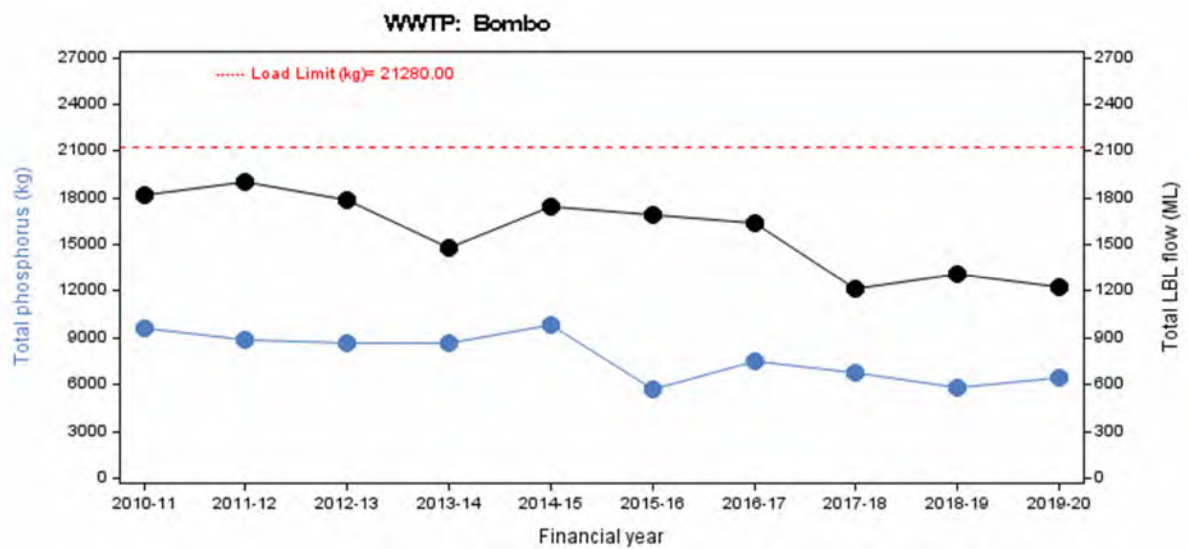
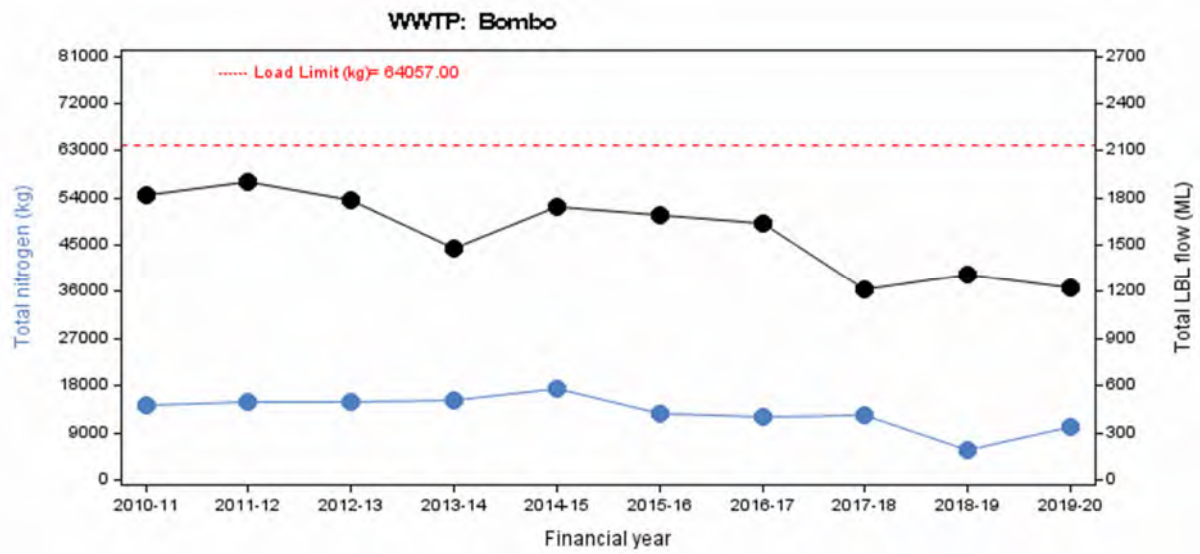


Note: Statistical test was not conducted because >90% of results were below the detection limit.

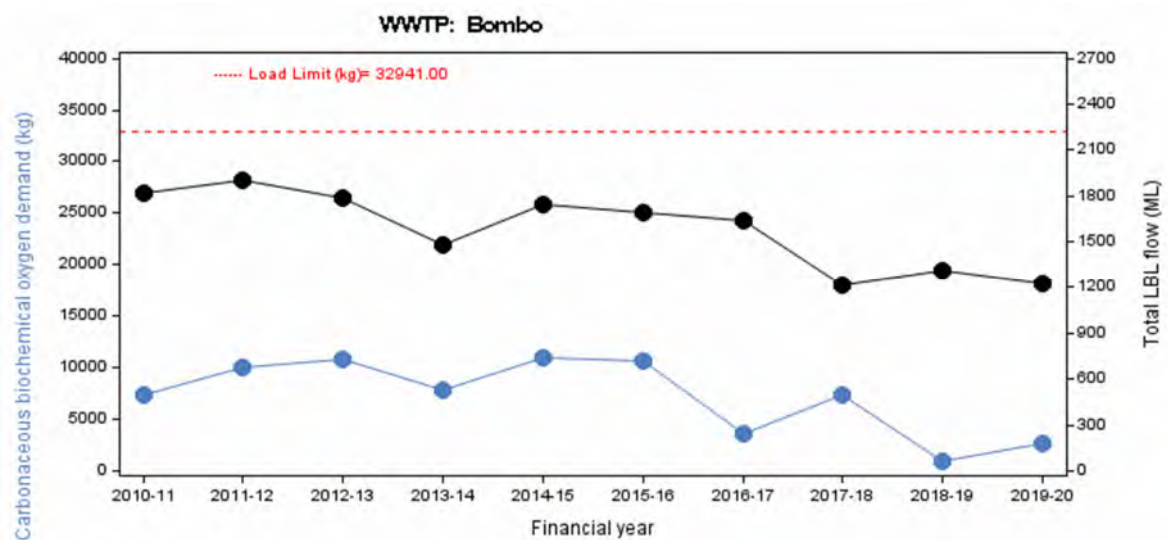


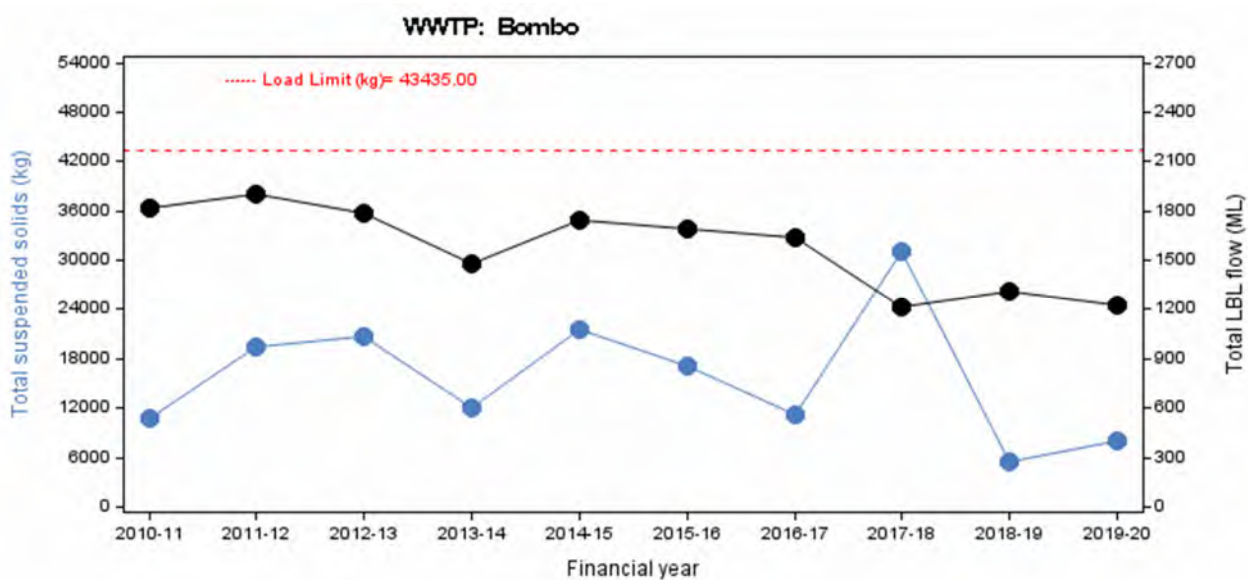
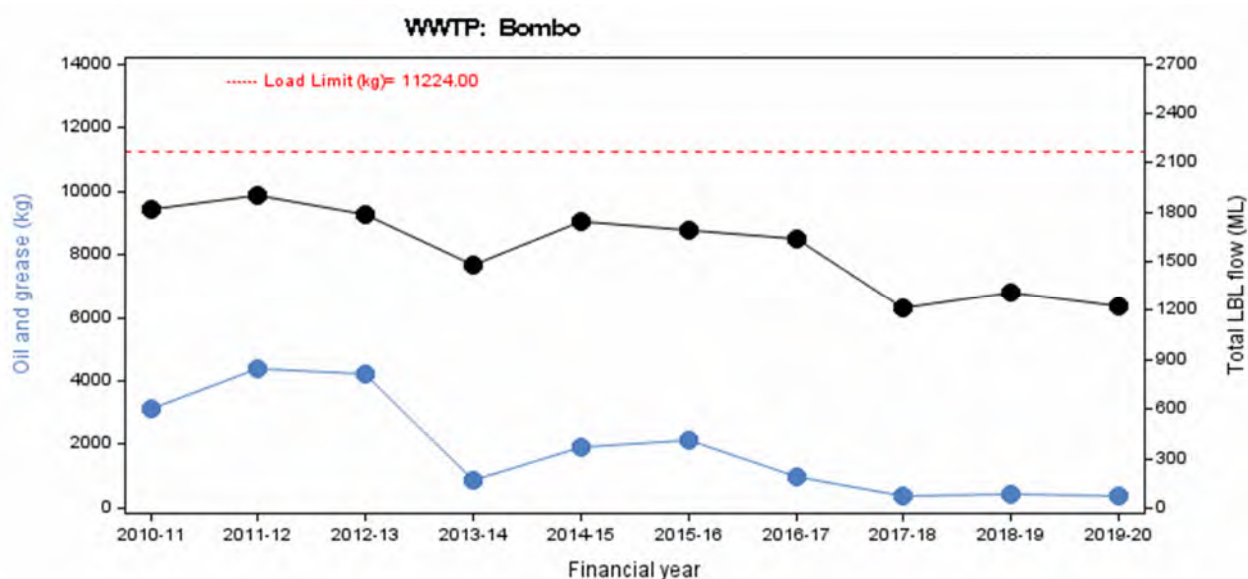
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2018) due to detection limit change in 2016-17.





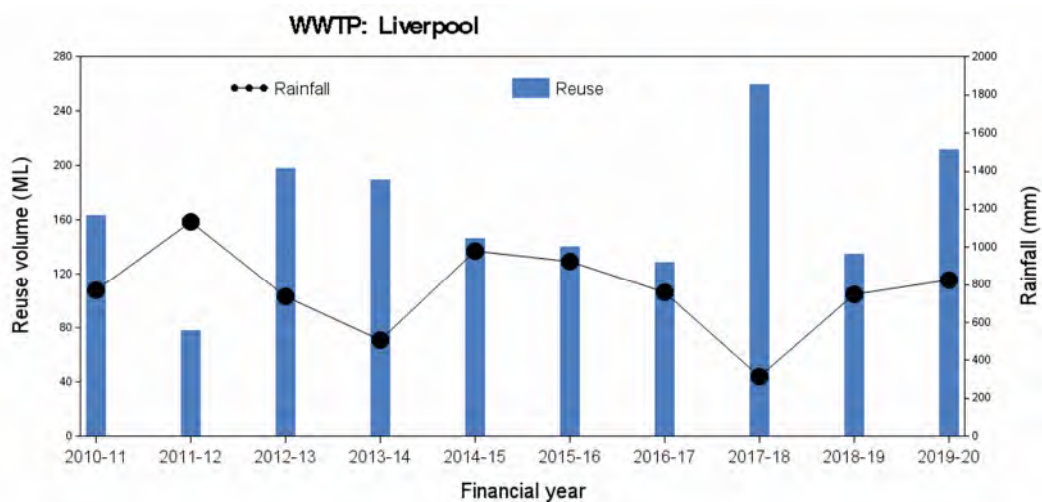
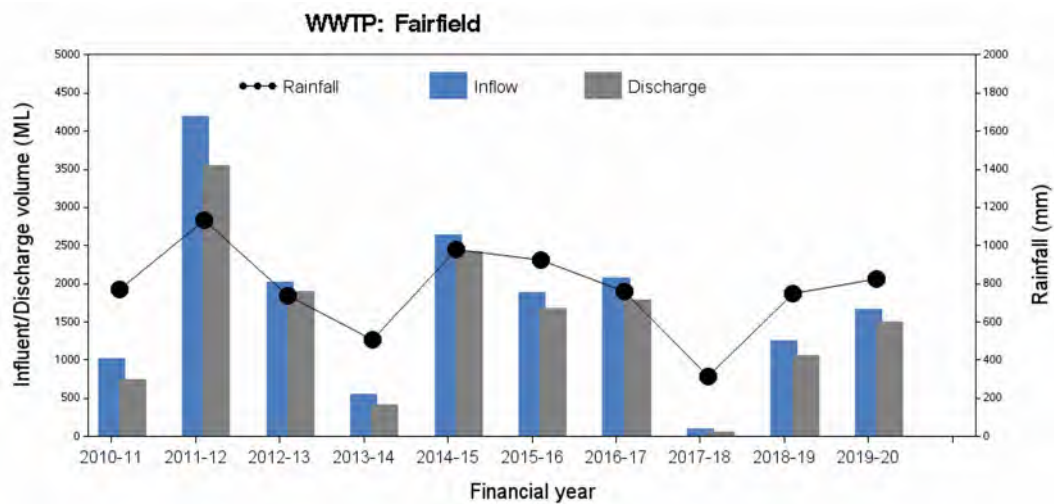
Discharge load: Major conventional analytes



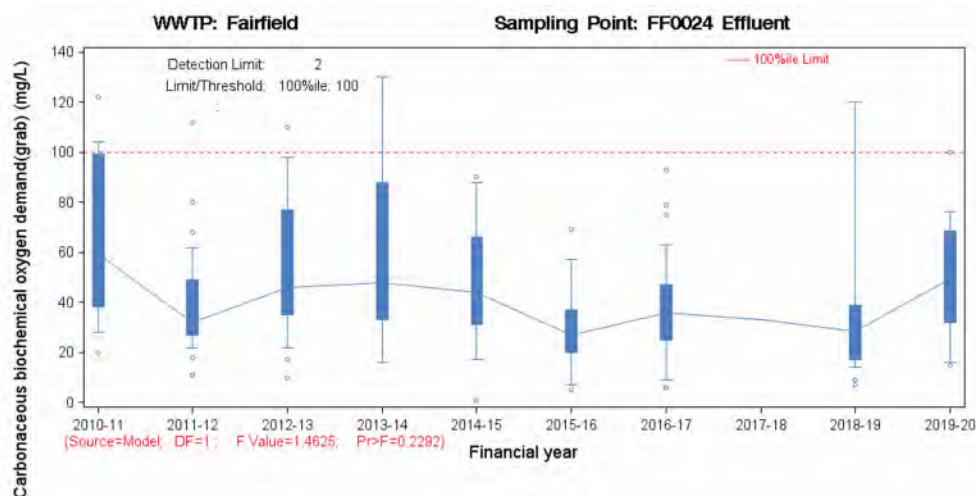


Malabar storm WWTPs (Fairfield, Glenfield and Liverpool)

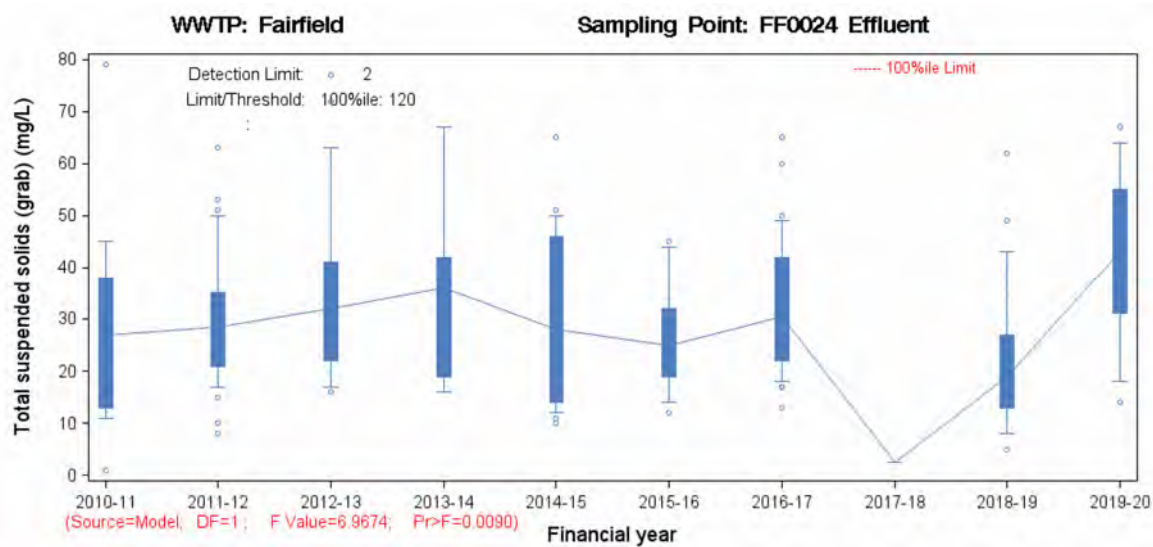
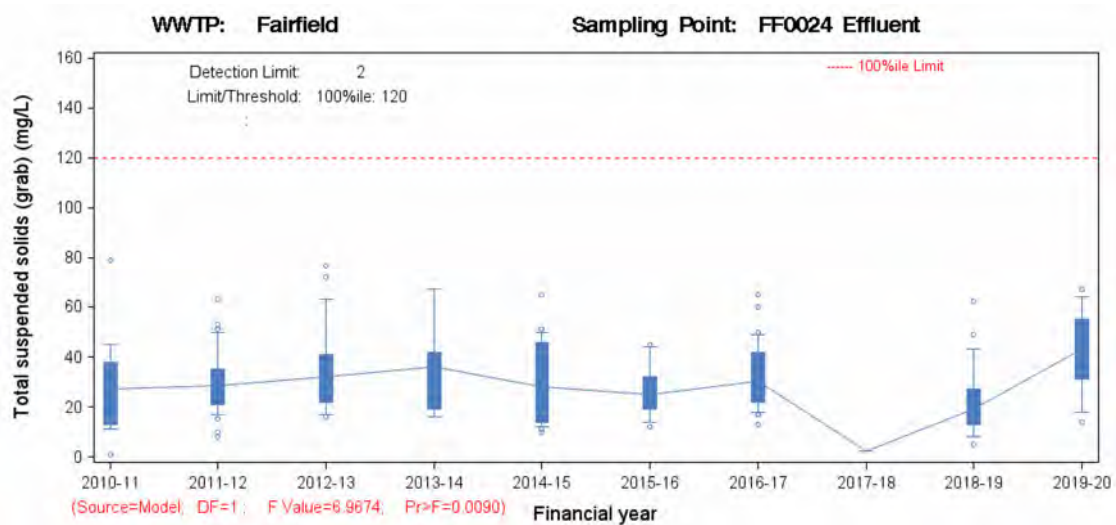
Discharge volume and rainfall (Fairfield)



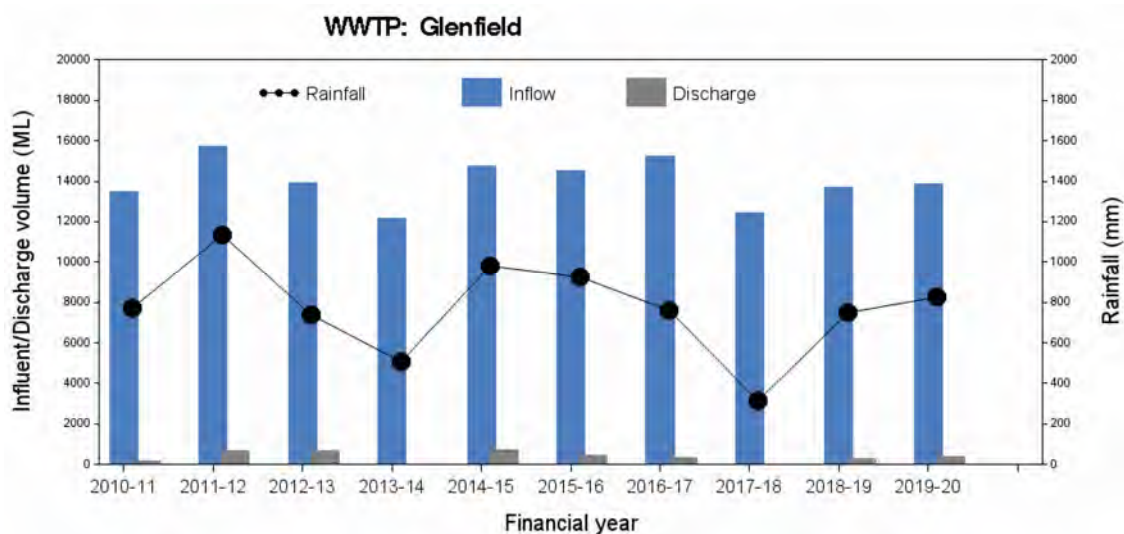
Discharge quality: Major conventional analytes (Fairfield)



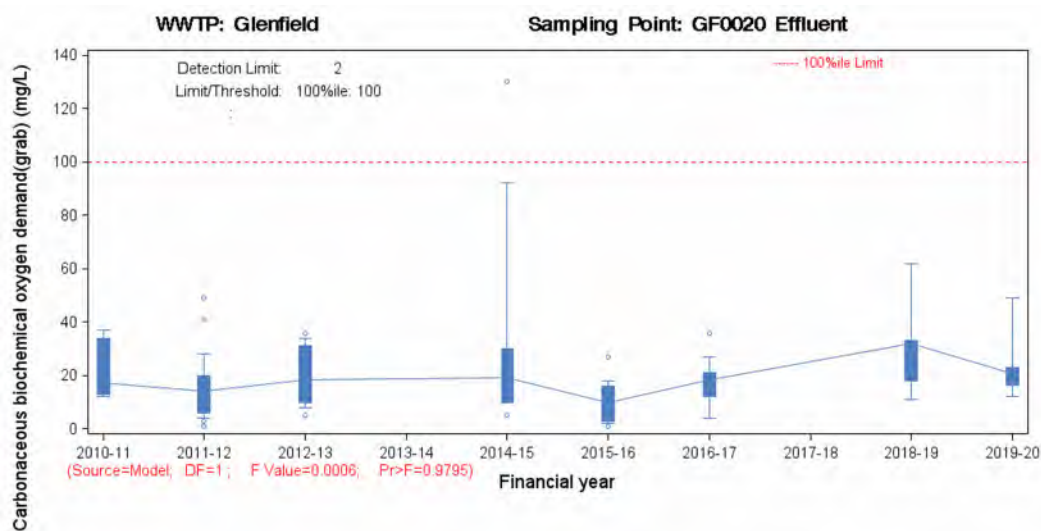
Note: Statistical test was based on 2019-20 data with previous five years data (2014-2019) due to lab method change in 2014-15.



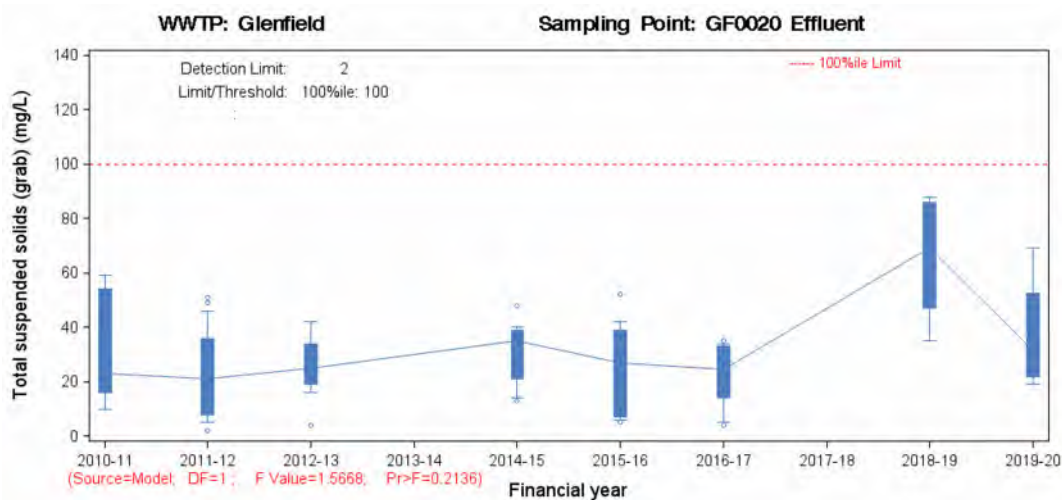
Discharge volume and rainfall (Glenfield)

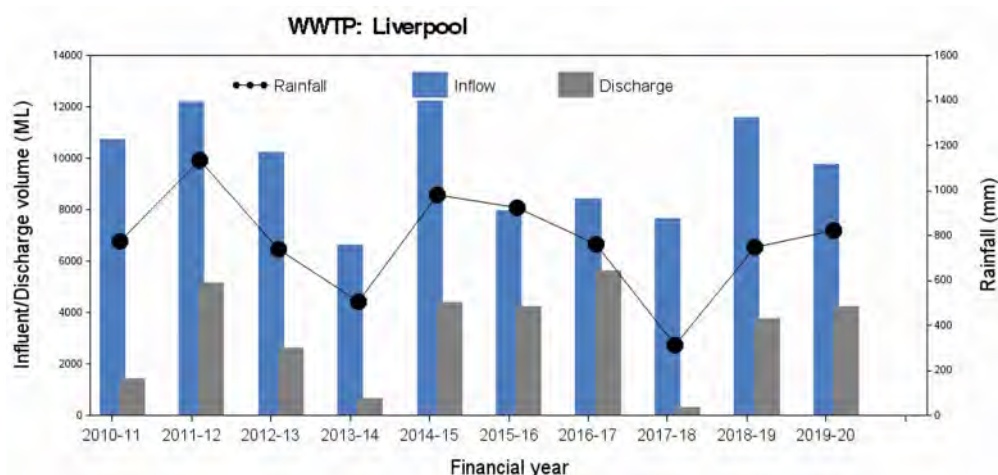


Discharge quality: Major conventional analytes (Glenfield)

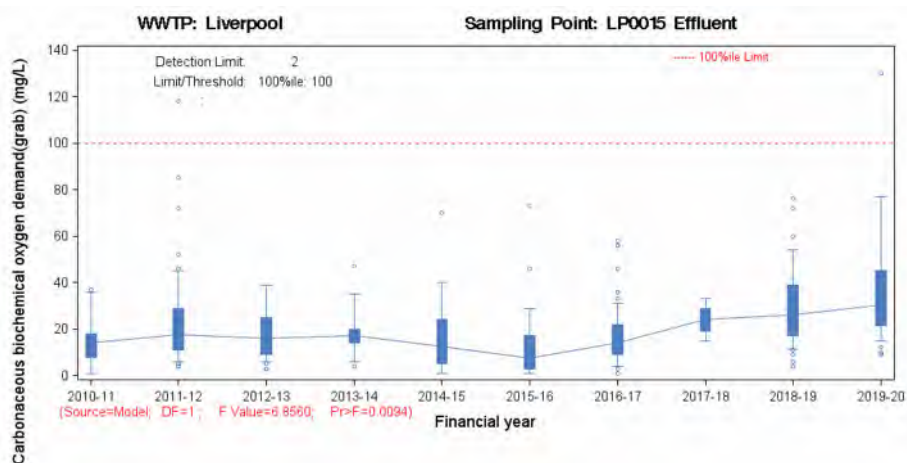


Note: Statistical test was based on 2019-20 data with previous five years data (2014-2019) due to lab method change in 2014-15.

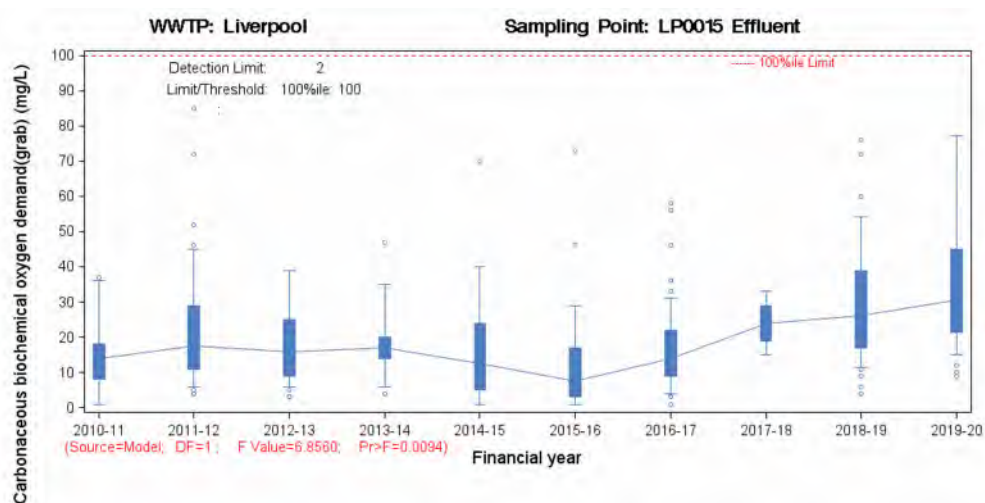




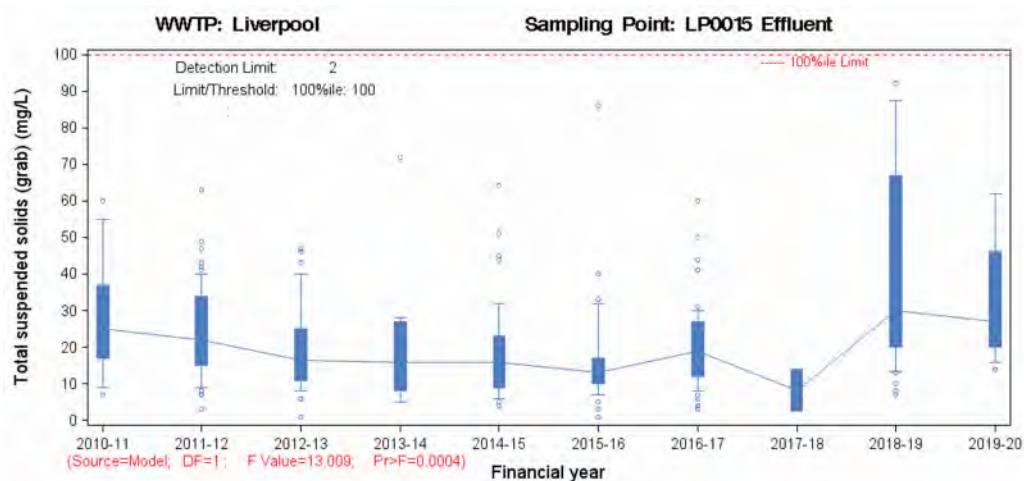
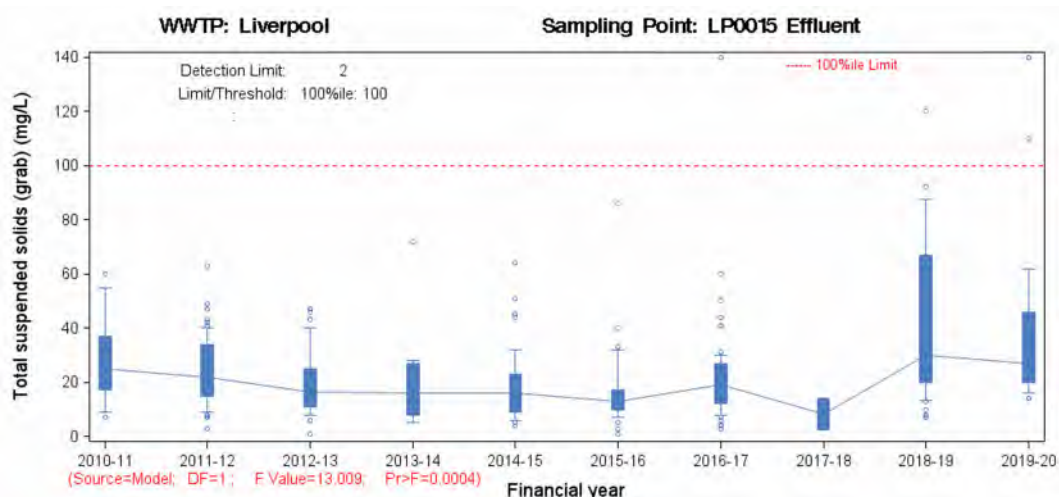
Discharge quality: Major conventional analytes (Liverpool: LP0015 – effluent diversion structure at Chipping Norton)



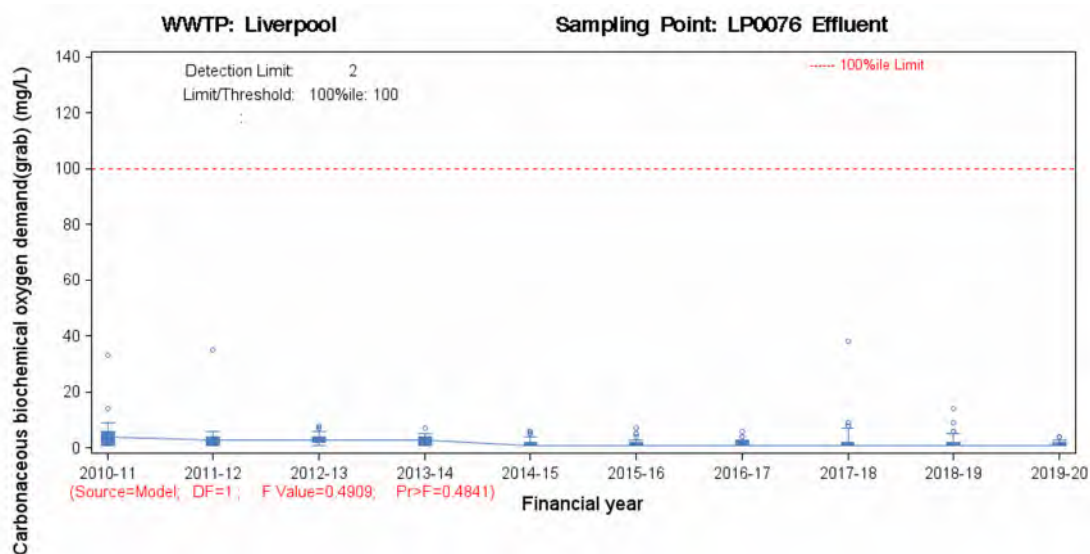
Note: Statistical test was based on 2019-20 data with previous five years data (2014-2019) due to lab method change in 2014-15.



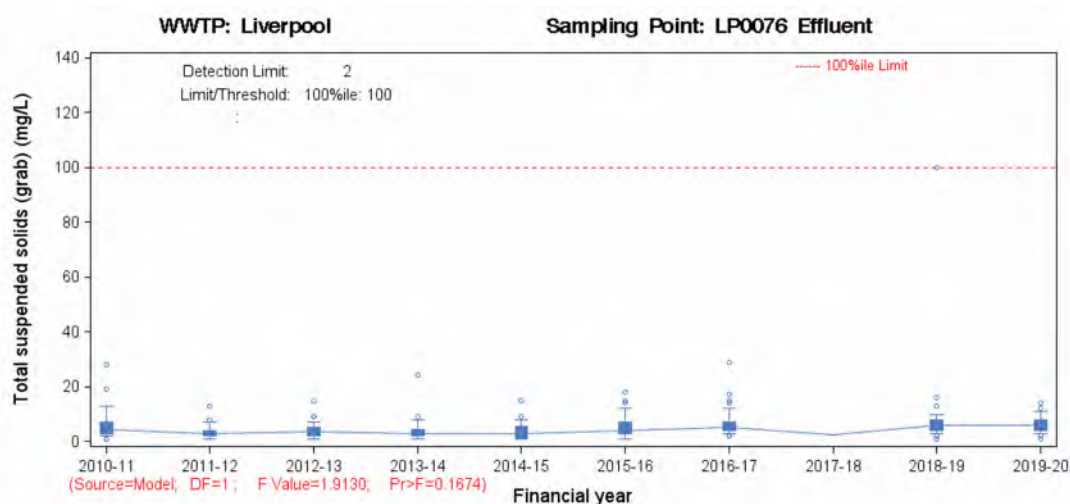
Note: Statistical test was based on 2019-20 data with previous five years data (2014-2019) due to lab method change in 2014-15.



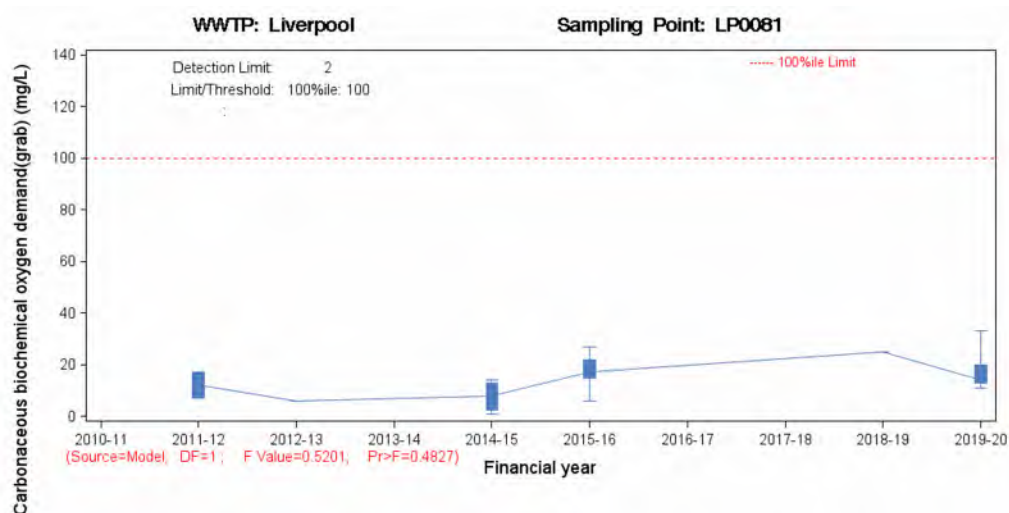
Discharge quality: Major conventional analytes (Liverpool: LP0076 – recycled water chlorine contact tank)



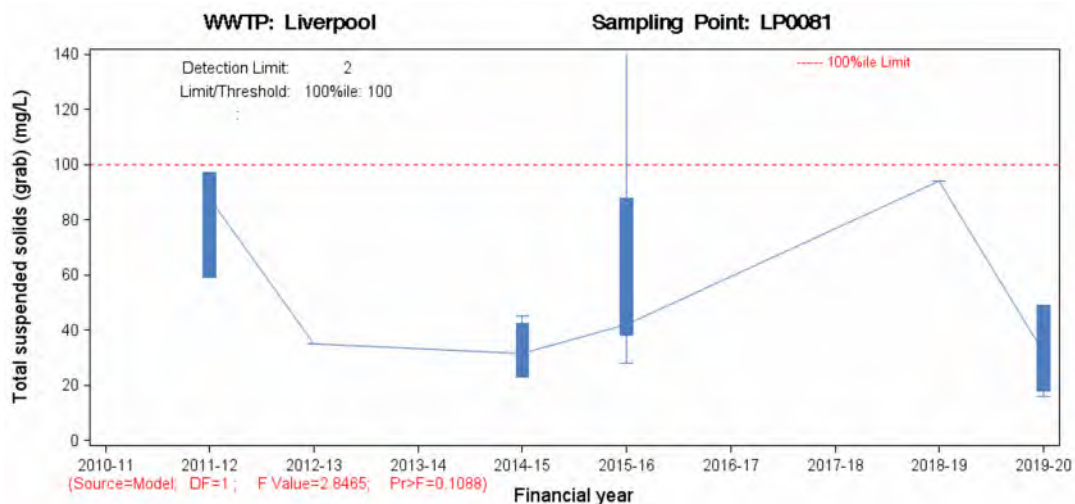
Note: Statistical test was based on 2019-20 data with previous five years data (2014-2019) due to lab method change in 2014-15.



Discharge quality: Major conventional analytes (Liverpool: LP0081 – overflow chamber downstream of chlorine contact tank)



Note: Statistical test was based on 2019-20 data with previous five years data (2014-2019) due to lab method change in 2014-15.





Appendix D: Trends in discharge and reuse volumes, discharge quality and pollutant loads from inland WWTPs

The inland WWTPs are presented in upstream to downstream locations of the Hawkesbury-Nepean River:

- Picton WWTP
- West Camden WWTP
- Wallacia WWTP
- Penrith WWTP
- Winmalee WWTP
- North Richmond WWTP
- Richmond WWTP
- St Marys WWTP
- Quakers Hill WWTP
- Riverstone WWTP
- Castle Hill WWTP
- Rouse Hill WWTP
- Hornsby Heights WWTP
- West Hornsby WWTP
- Brooklyn WWTP

Tests conducted on wastewater are specified in the Environment Protection Licences (EPL) issued by the NSW EPA for each WWTP. All measured analytes that have EPL concentration and load limits are presented on the following pages.

Under each WWTP, trend plots are presented on:

- Discharge and reuse volume
- Discharge quality
- Discharge loads

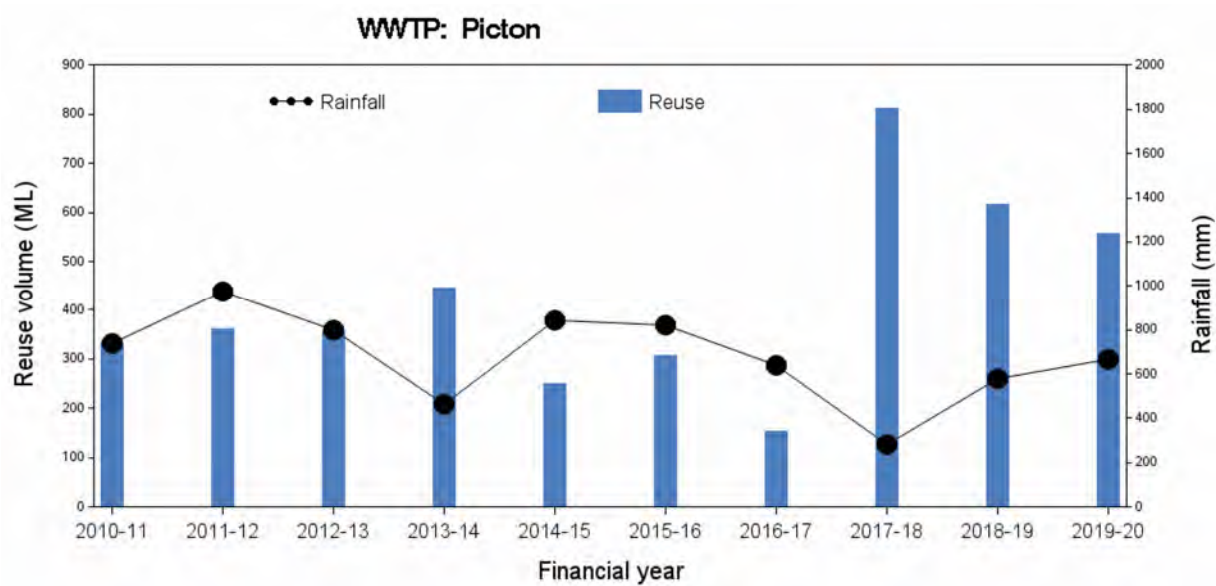
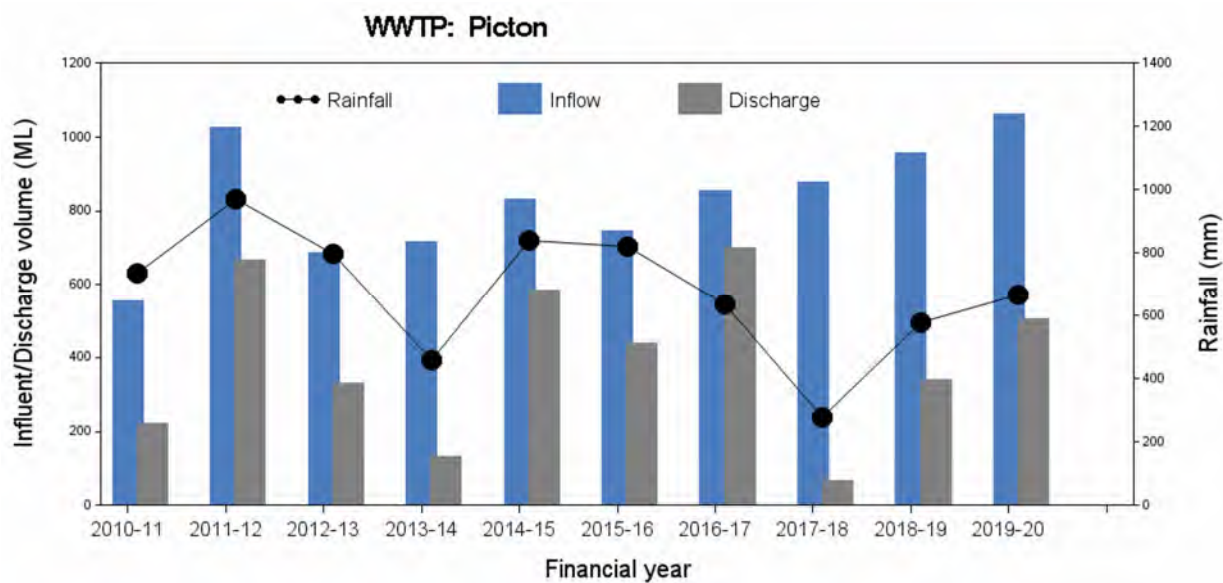
Discharge quality and load plots are included in following sub-groups and then analytes presented in alphabetical order:

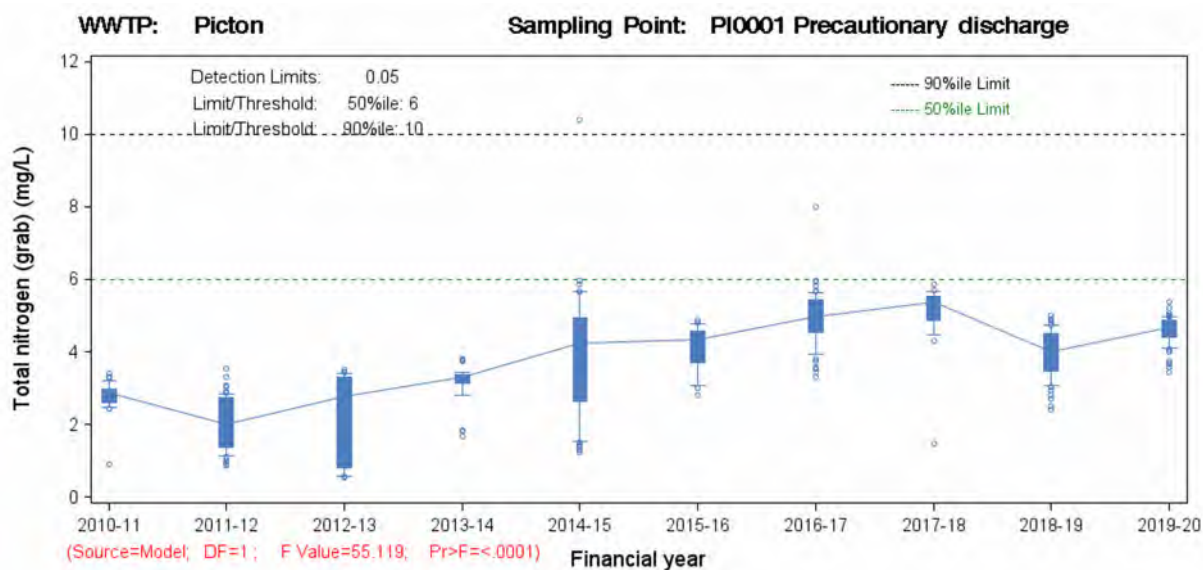
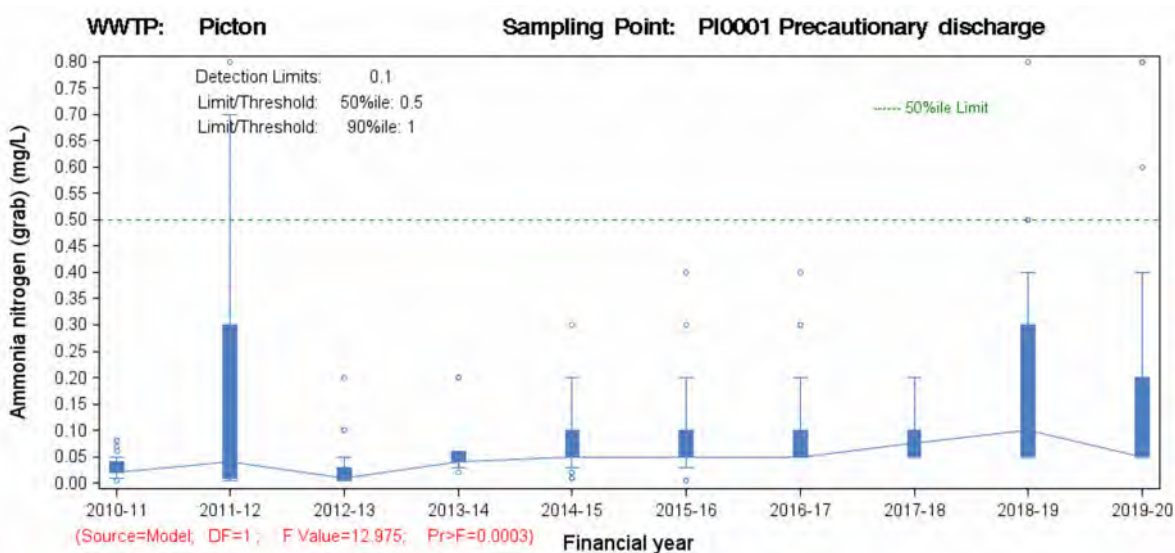
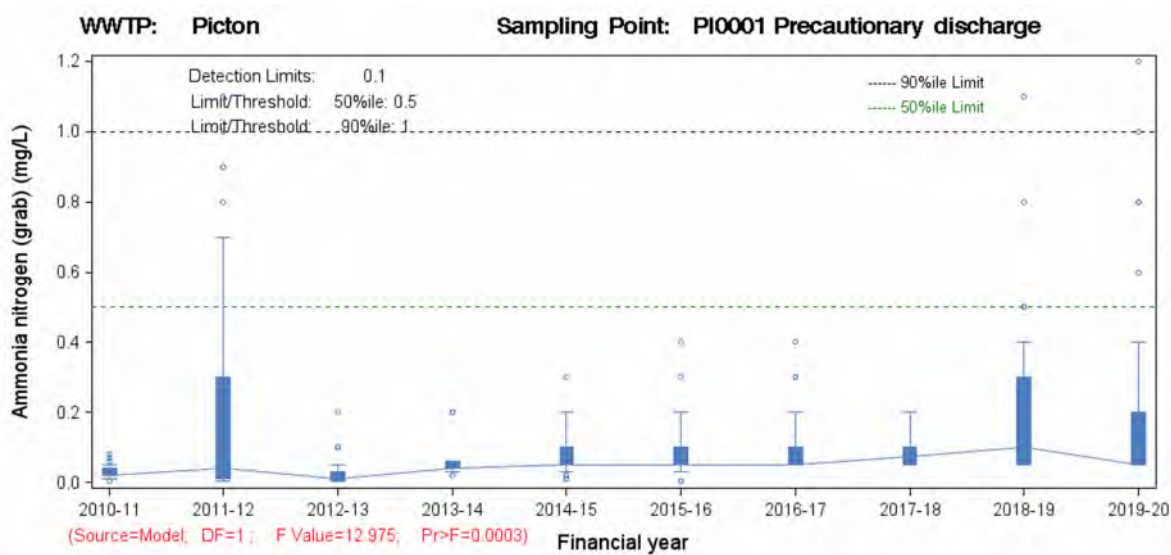
- Nutrients
- Major conventional analytes
- Toxicity
- Trace metals
- Other chemicals and organics (including pesticides)

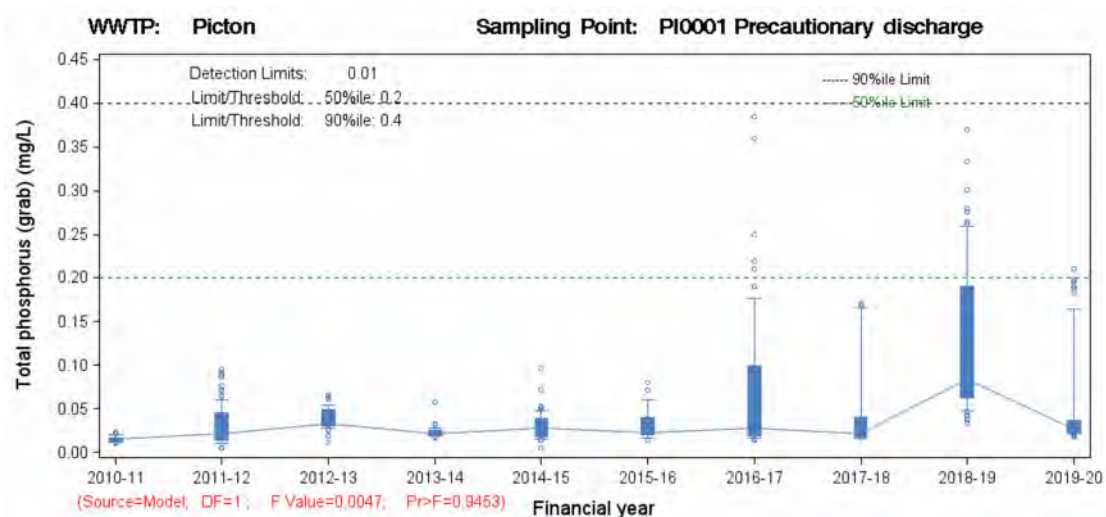
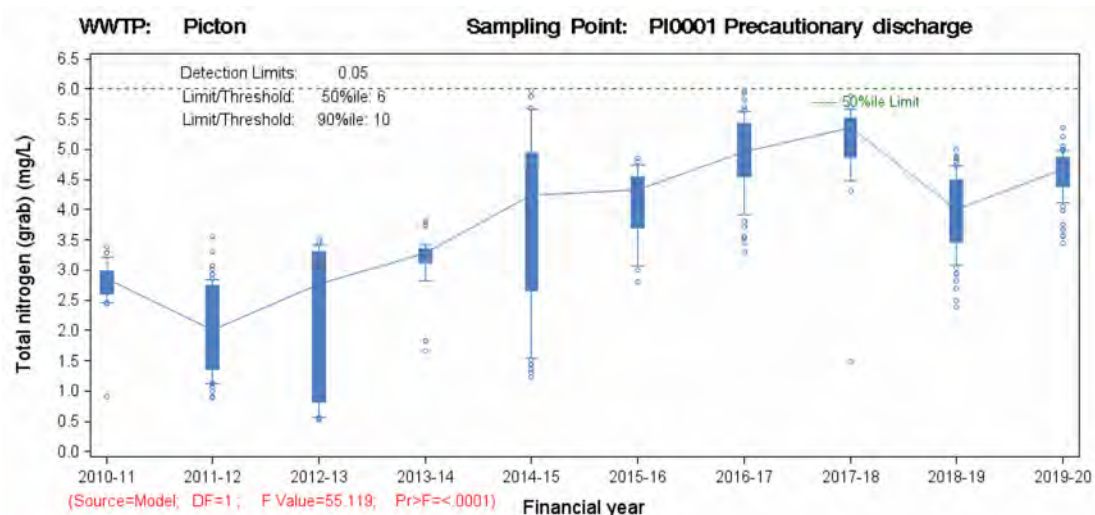
Where an analyte shows a trend (positive or negative) two plots are presented (where required) - one with the licence limits and one zoomed in to provide a clearer view of the trend.

Picton WWTP

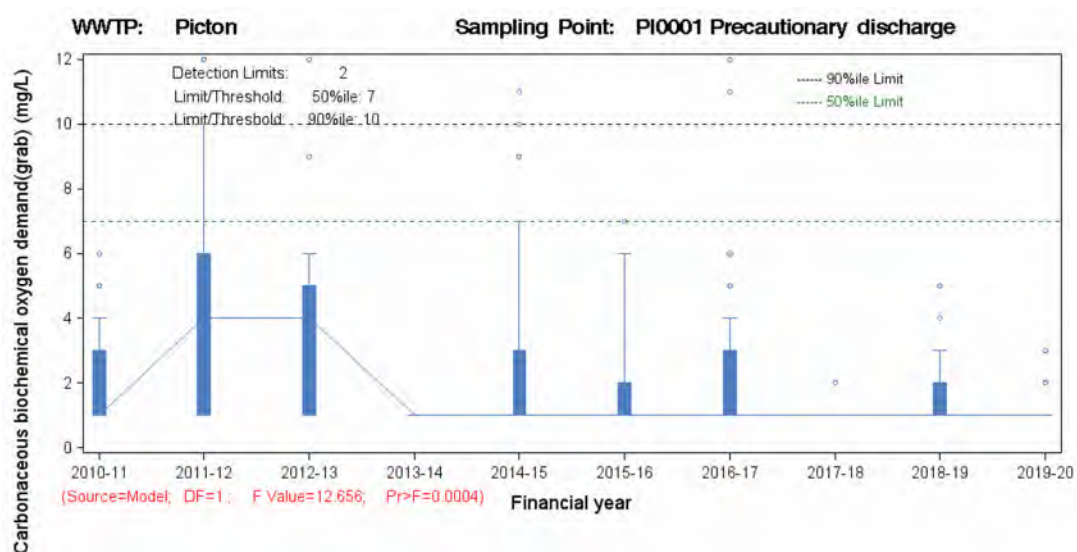
Discharge volume and rainfall



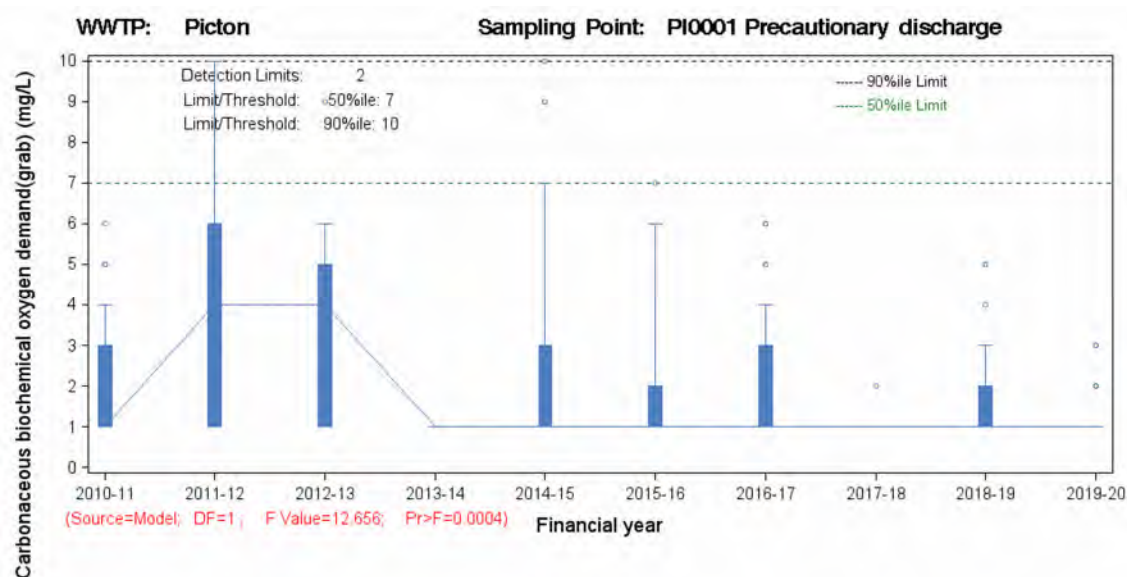




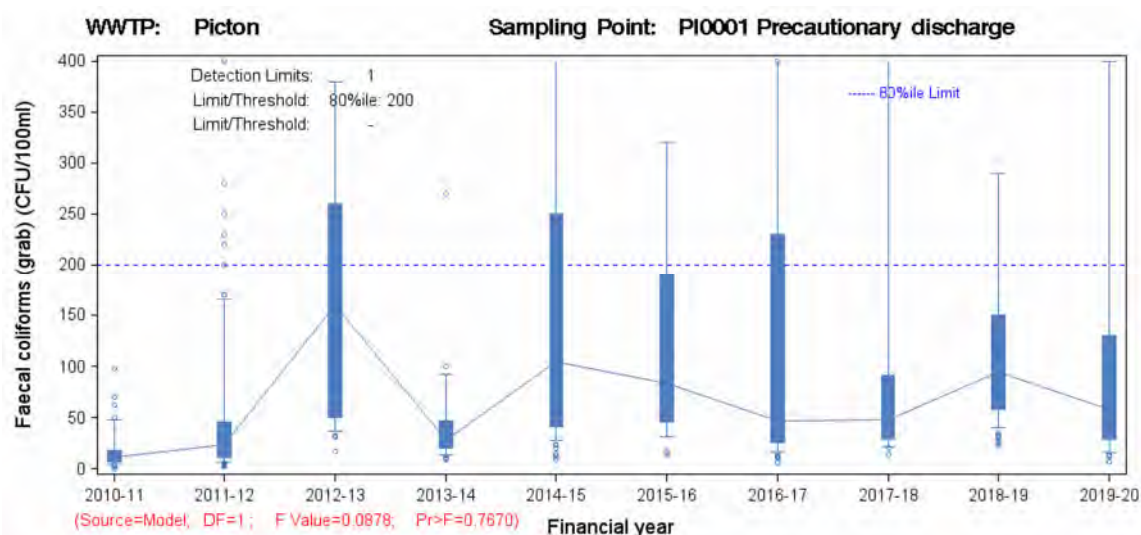
Discharge quality: Major conventional analytes (PI0001 Precautionary discharge)

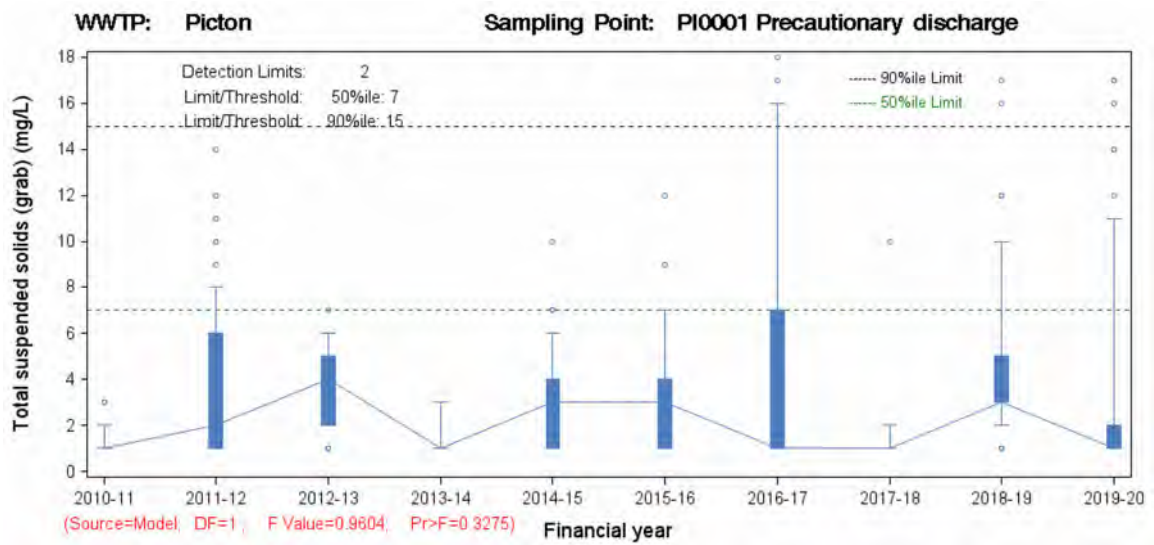


Note: Statistical test was based on 2019-20 data with previous five years data (2014-19) due to lab method change in 2014-15.

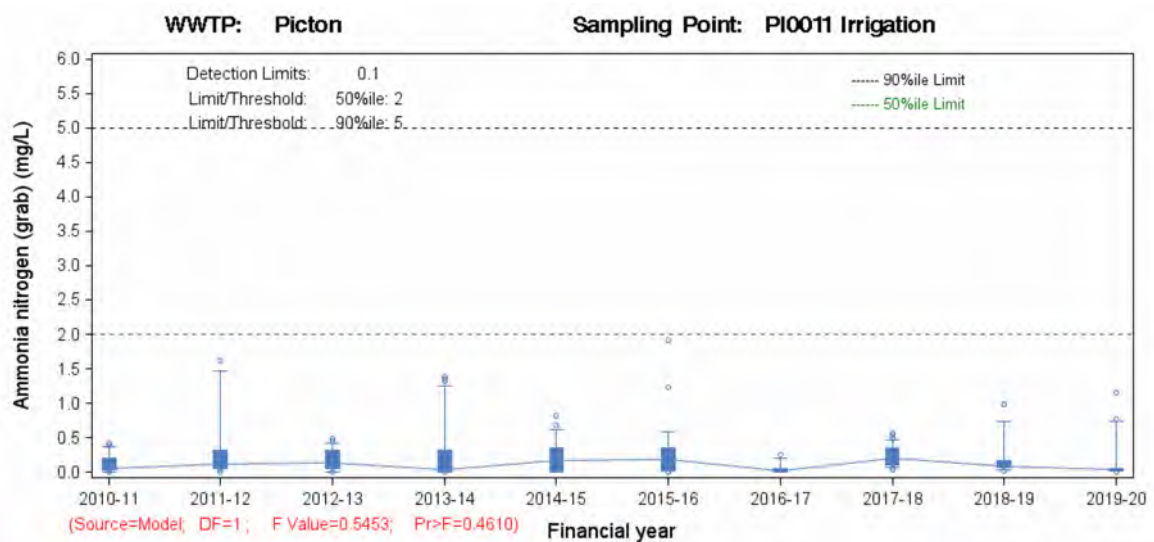


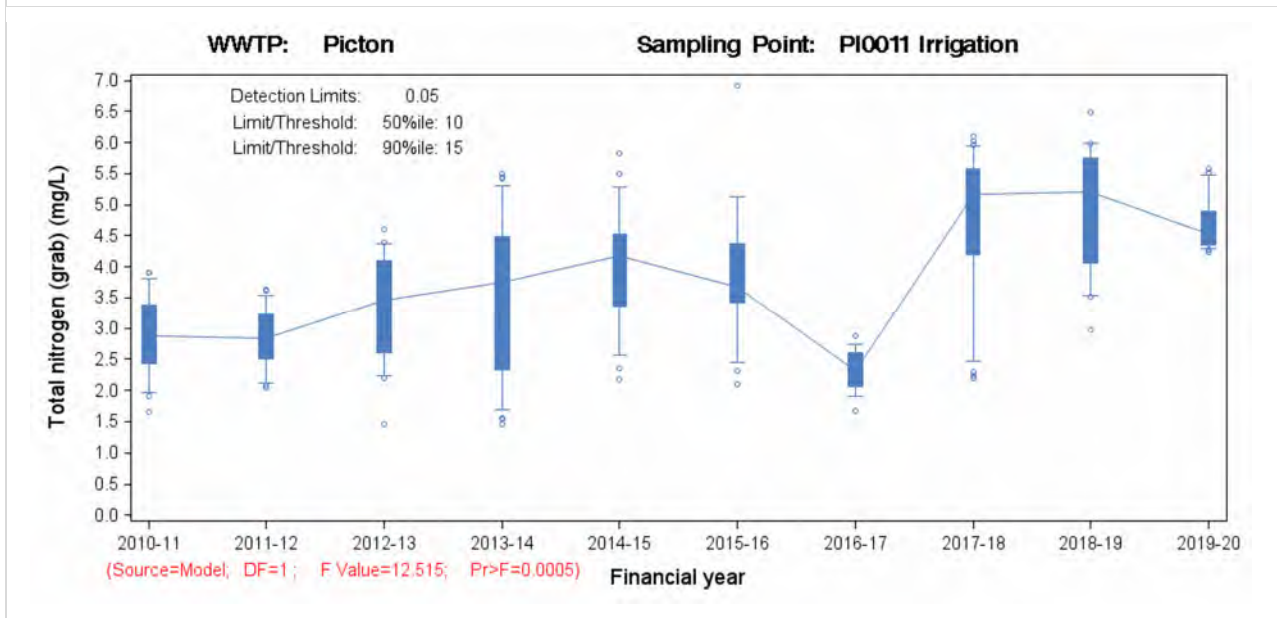
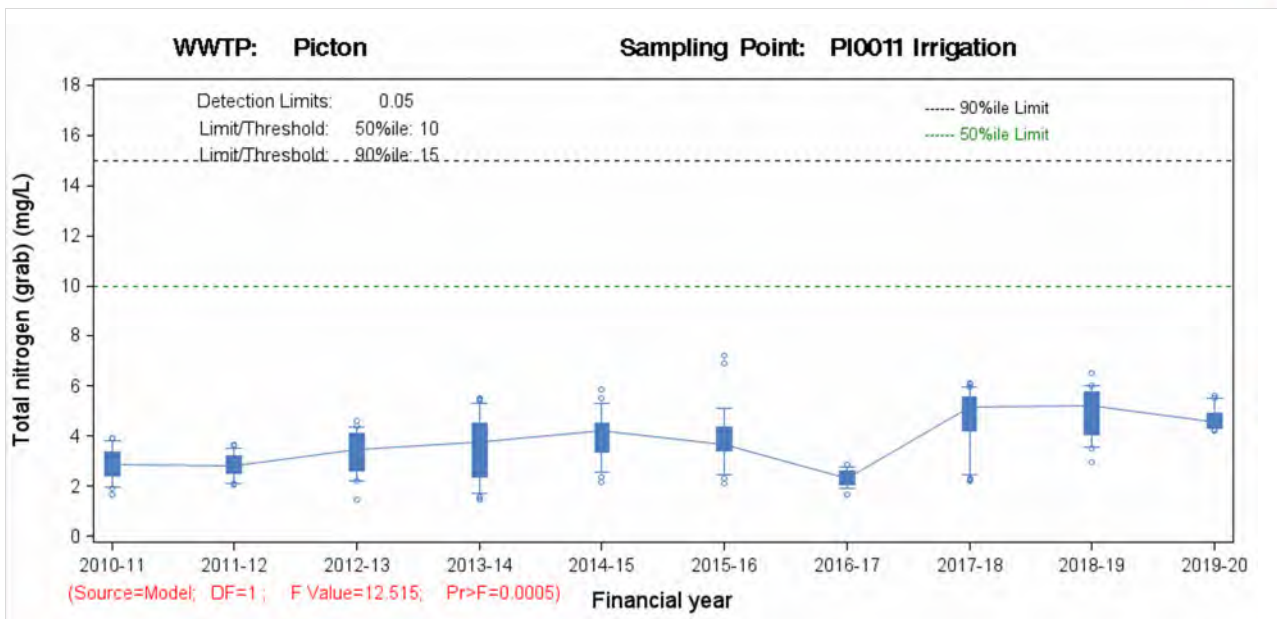
Note: Statistical test was based on 2019-20 data with previous five years data (2014-19) due to lab method change in 2014-15.

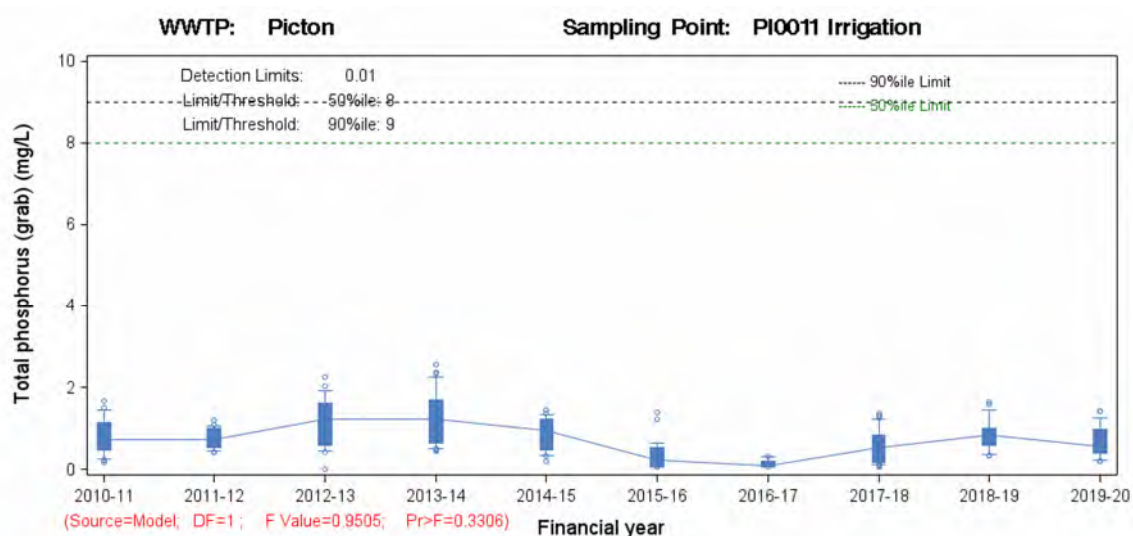




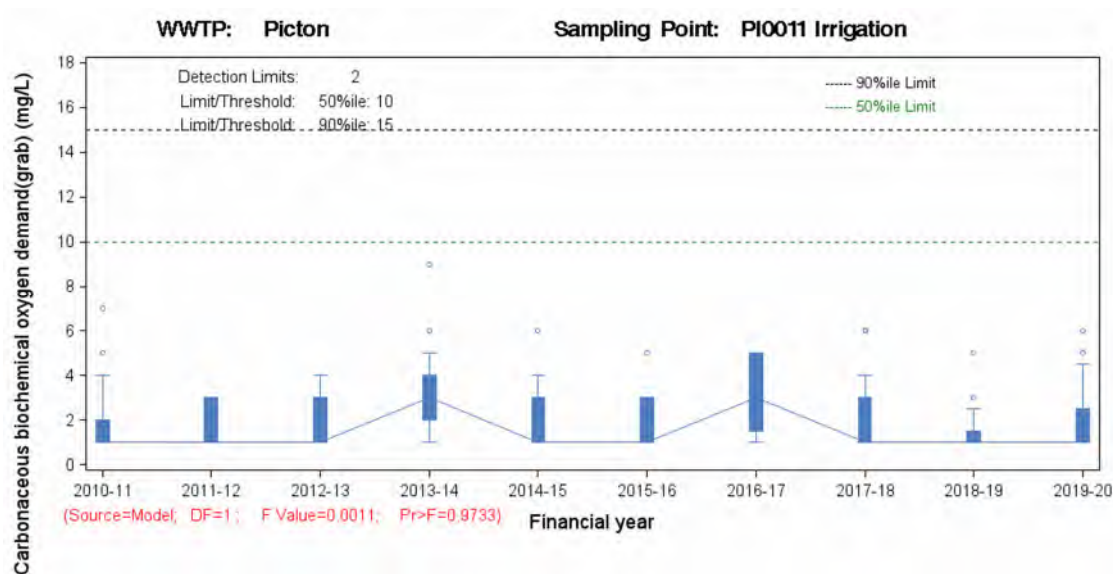
Discharge quality: Nutrients (PI0011 Irrigation)



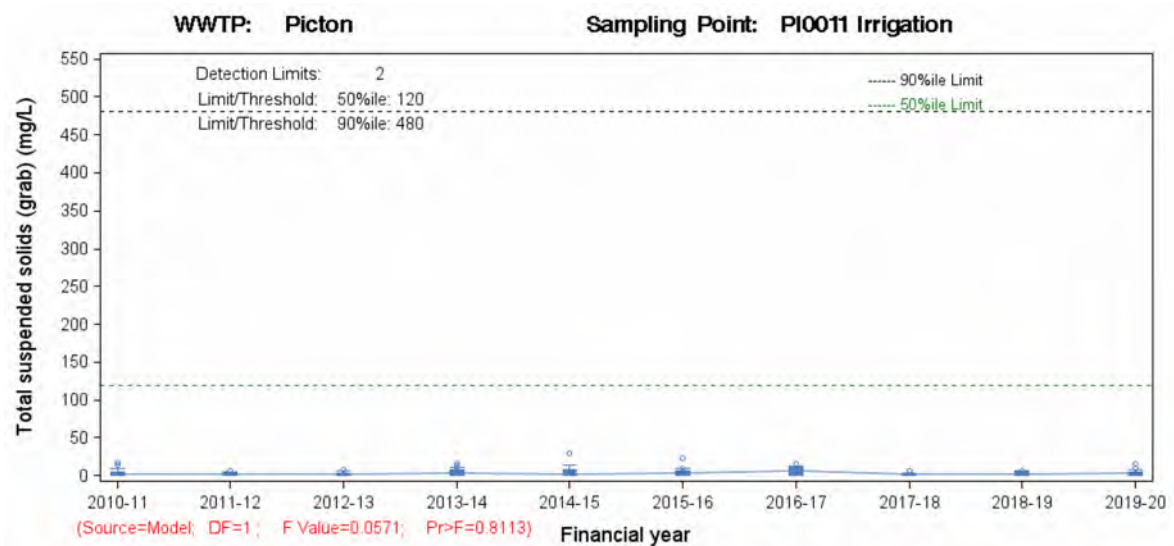
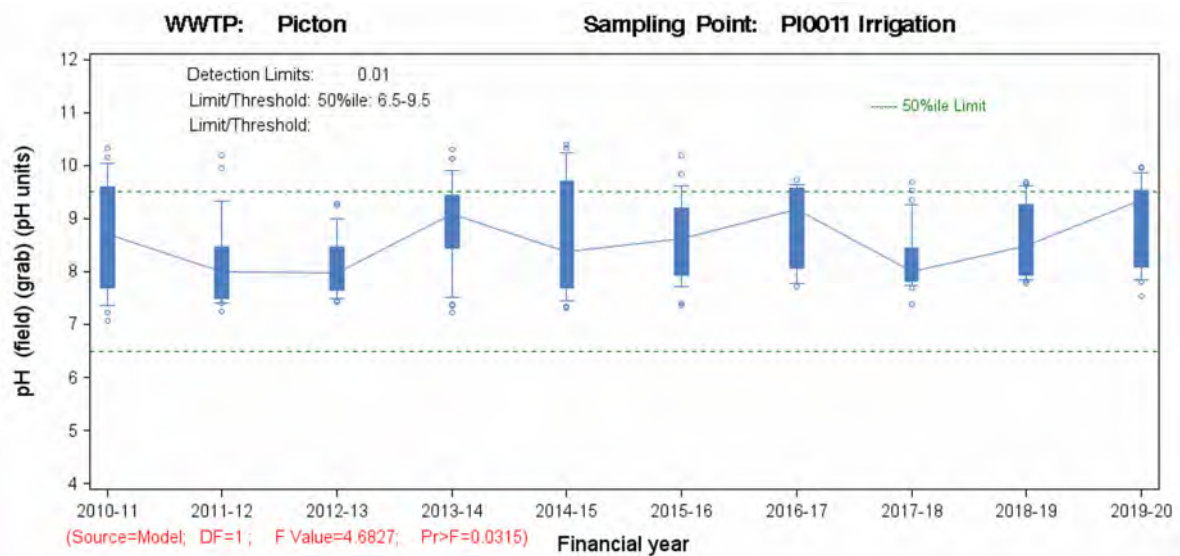
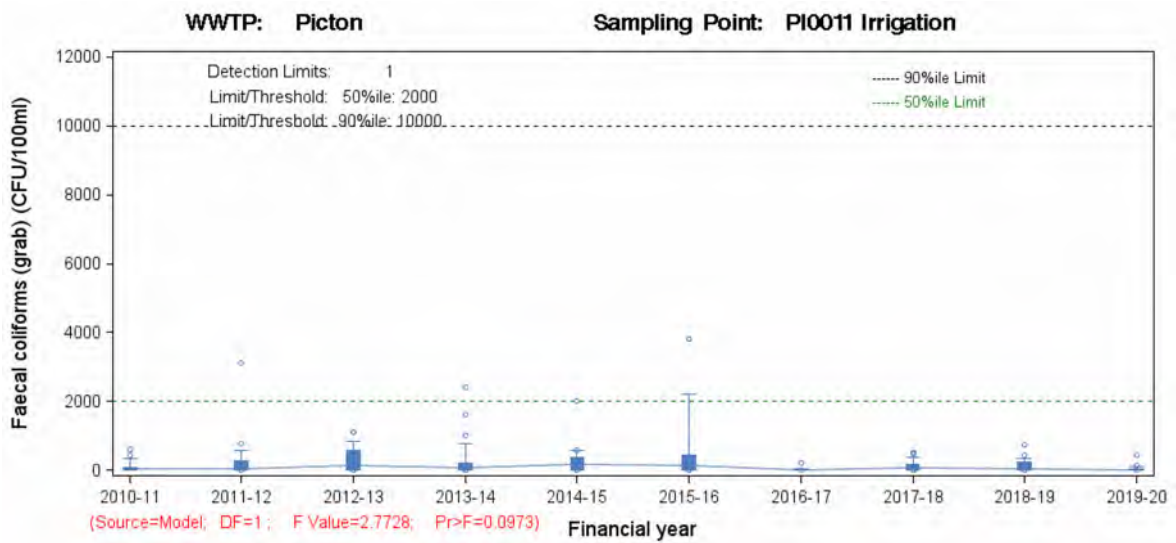




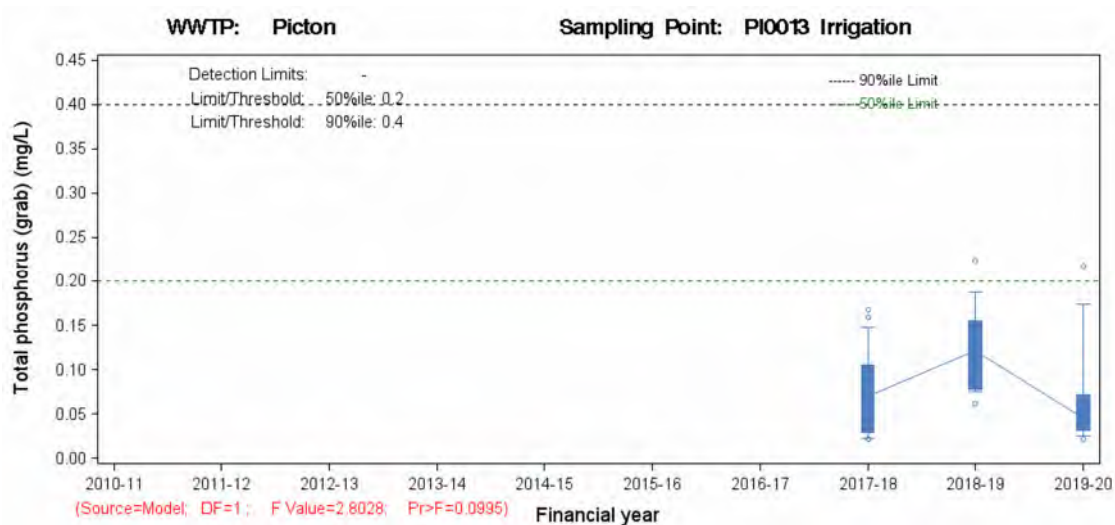
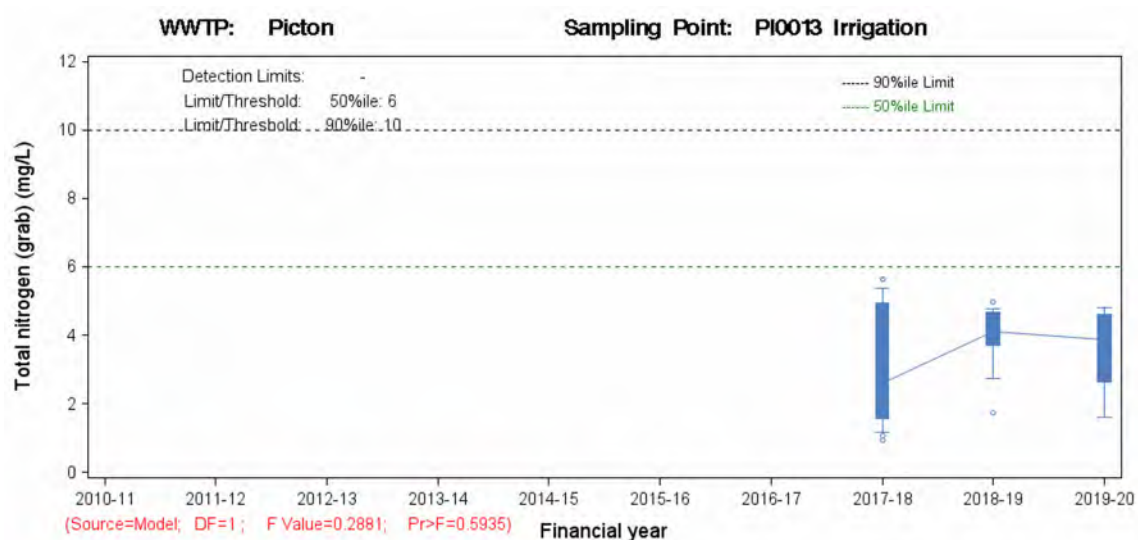
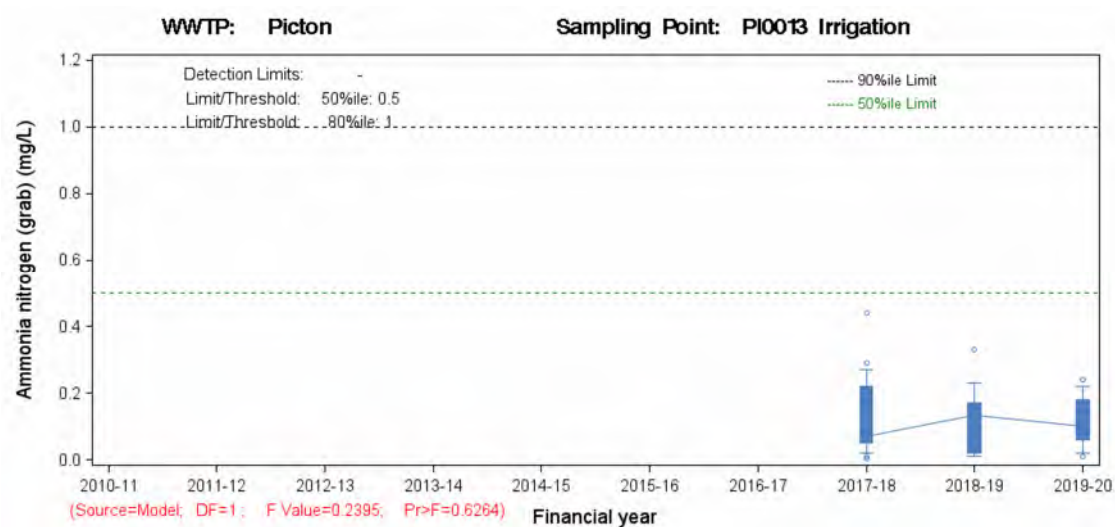
Discharge quality: Major conventional analytes (PI0011 Irrigation)



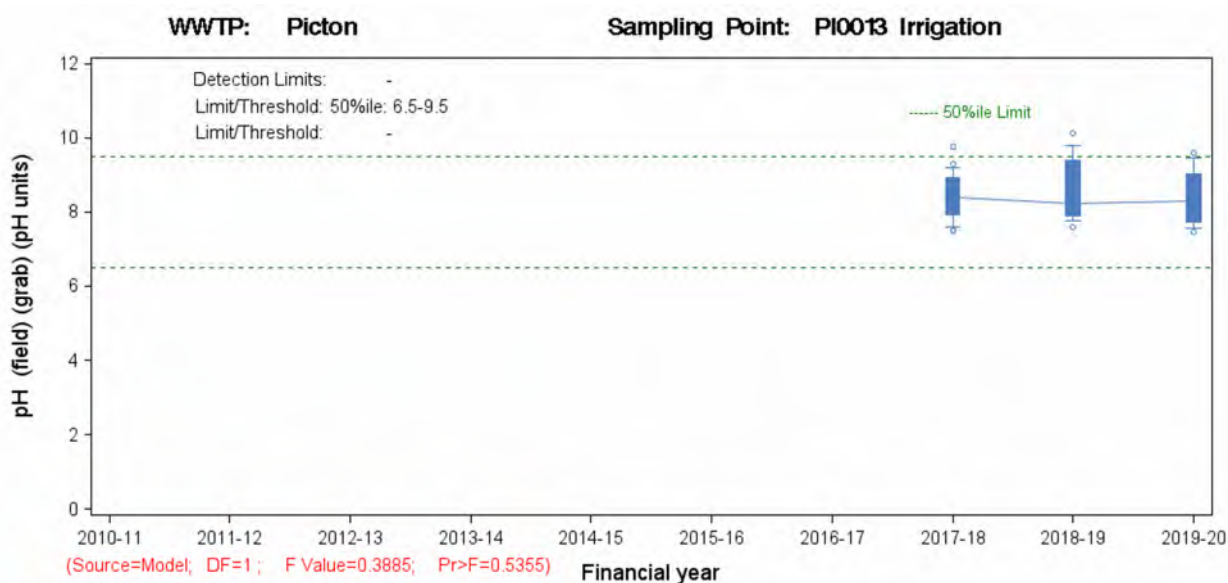
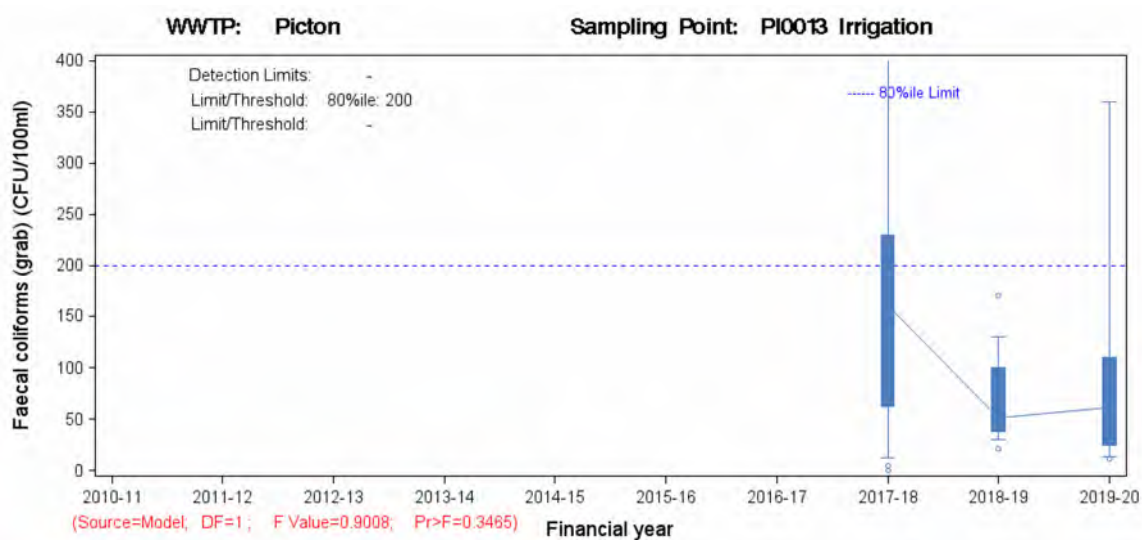
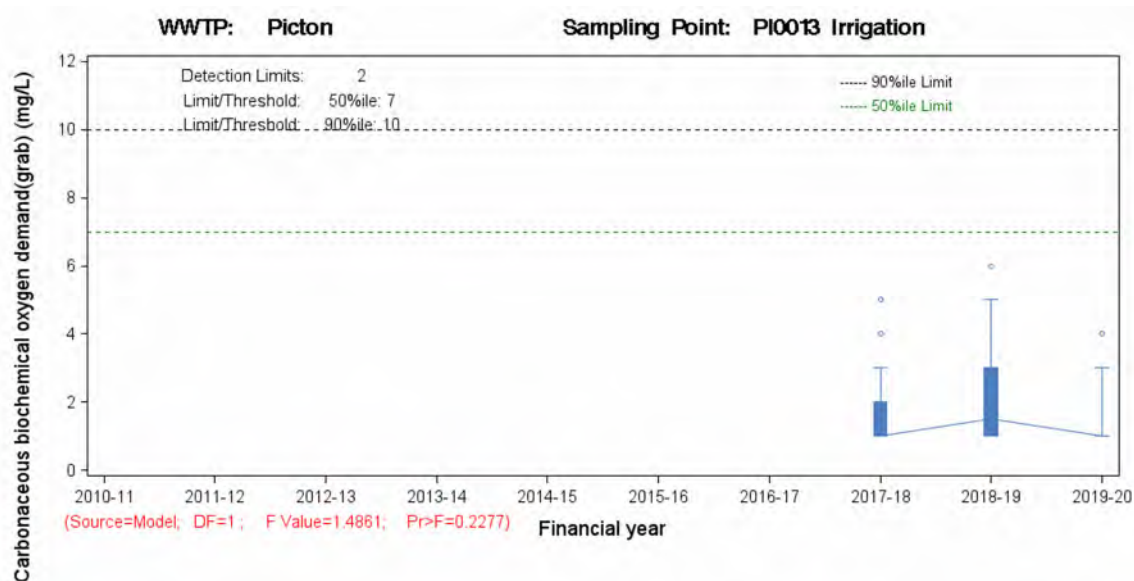
Note: Note: Statistical test was based on 2019-20 data with previous five years data (2014-19) due to lab method change in 2014-15

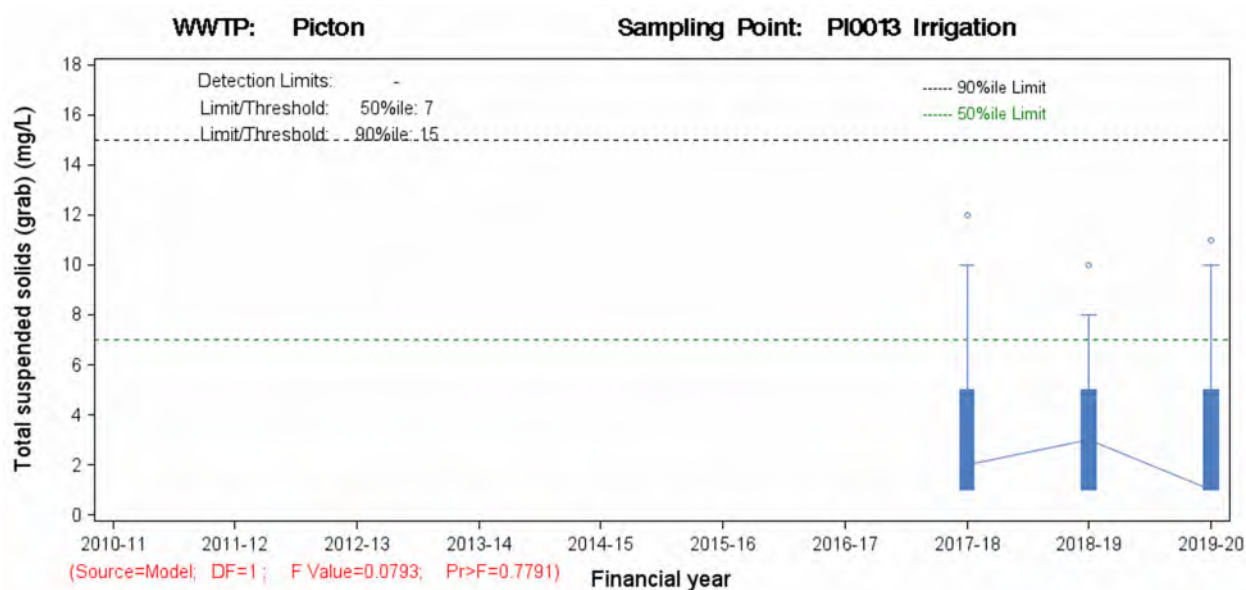


Discharge quality: Nutrients (PI0013 Irrigation)

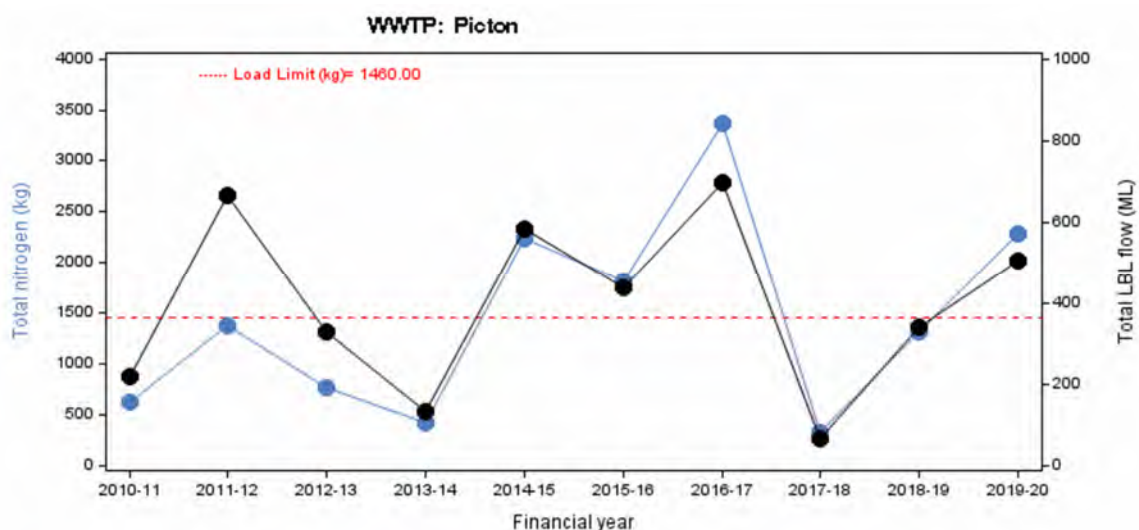


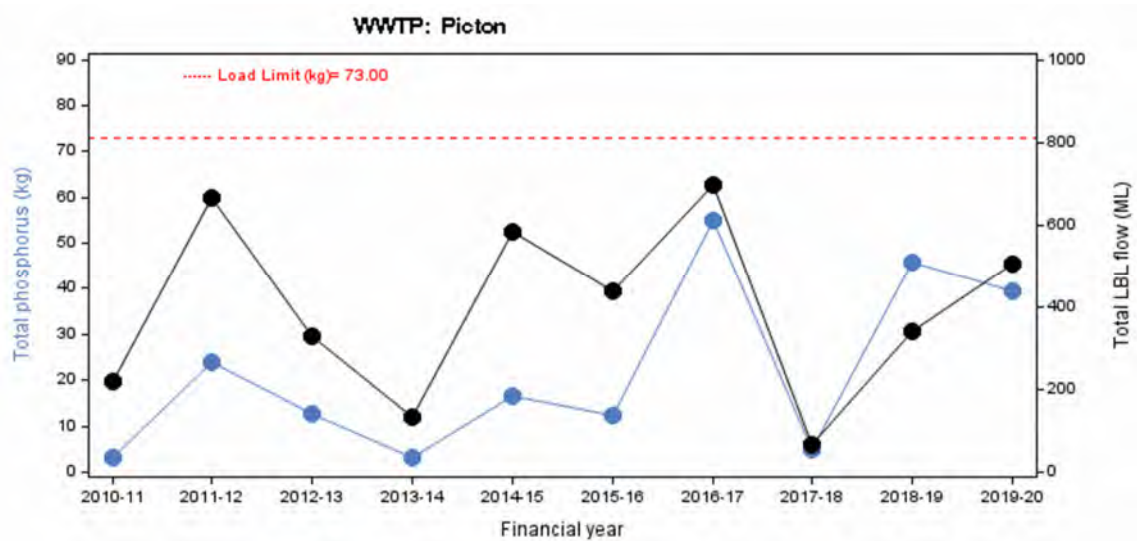
Discharge quality: Major conventional analytes (PI0013 Irrigation)



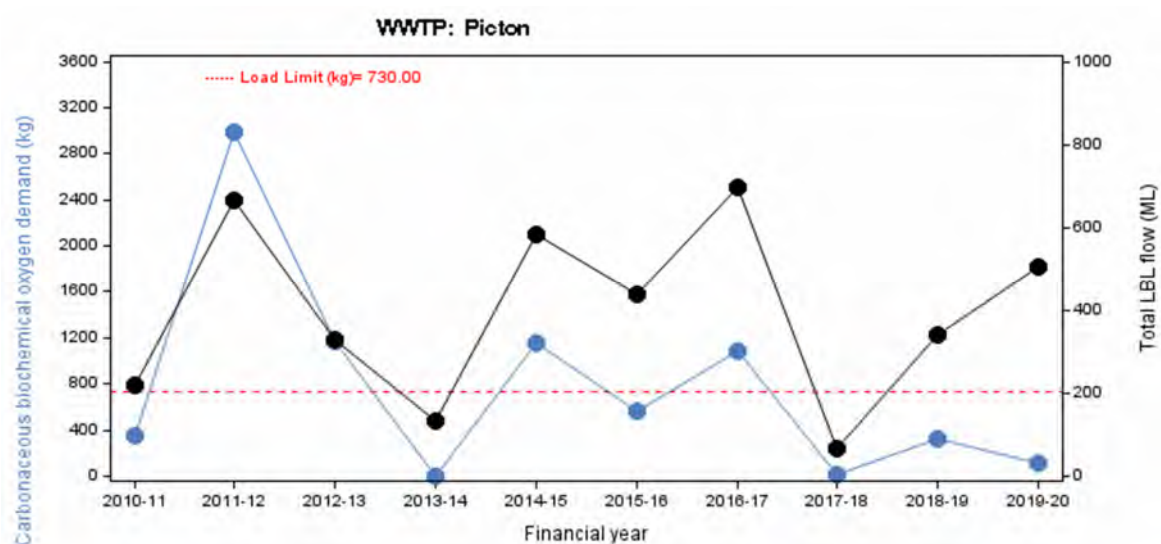


Discharge load: Nutrients

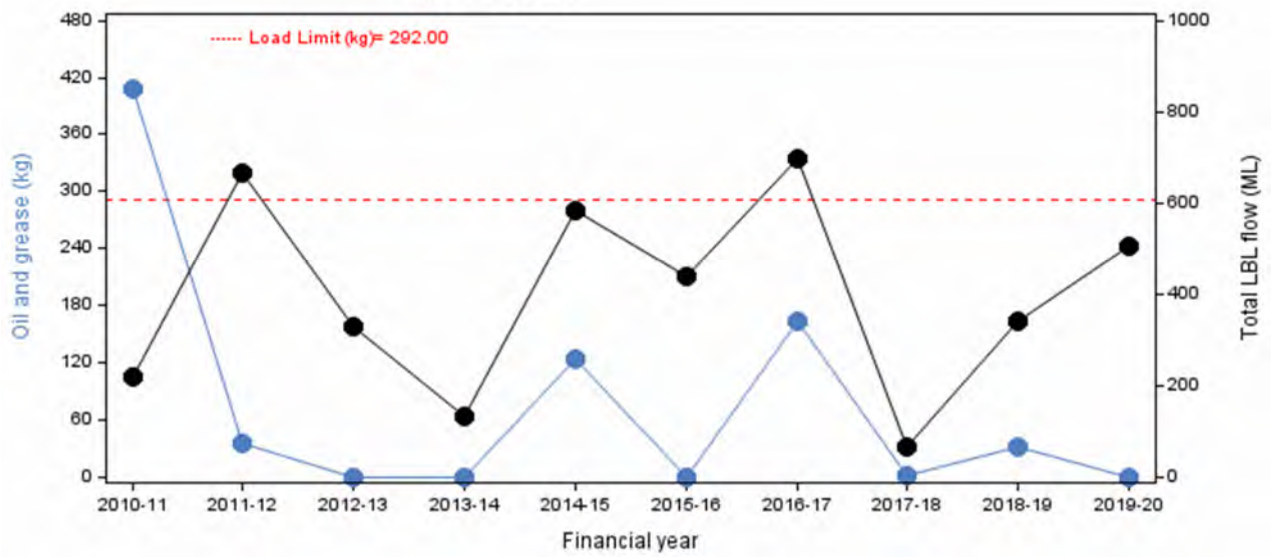




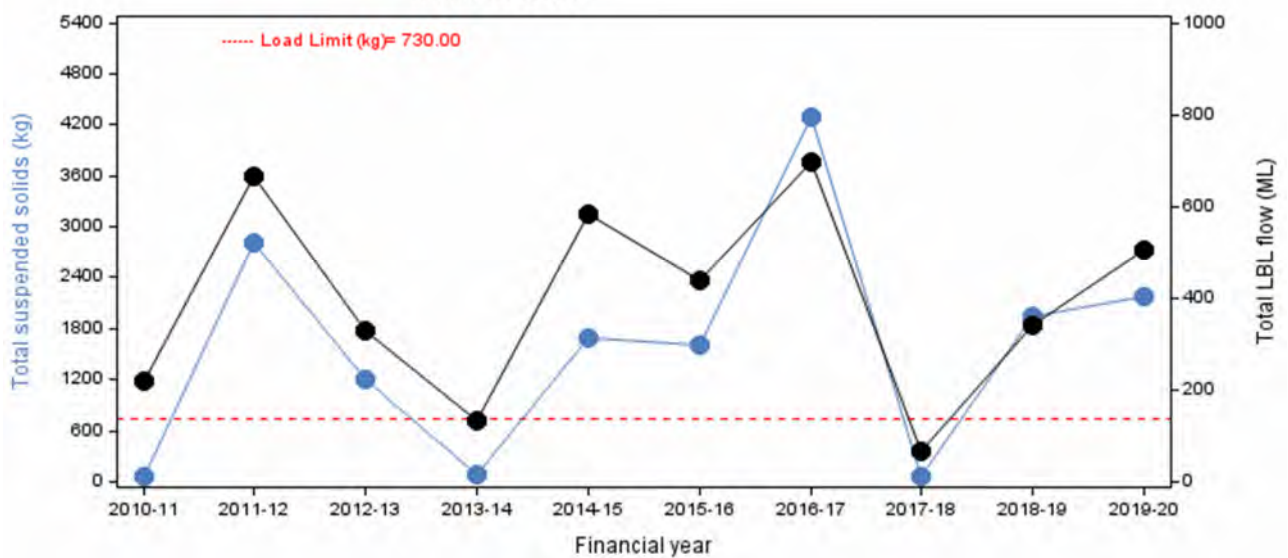
Discharge load: Major conventional analytes



WWTP: Pictou

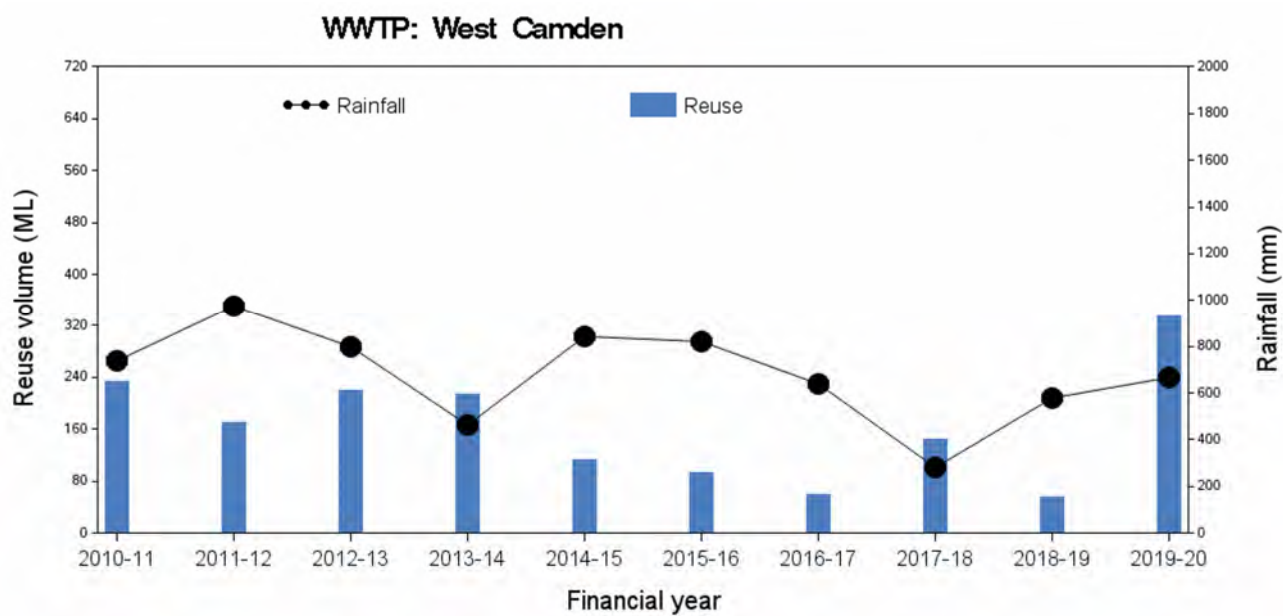
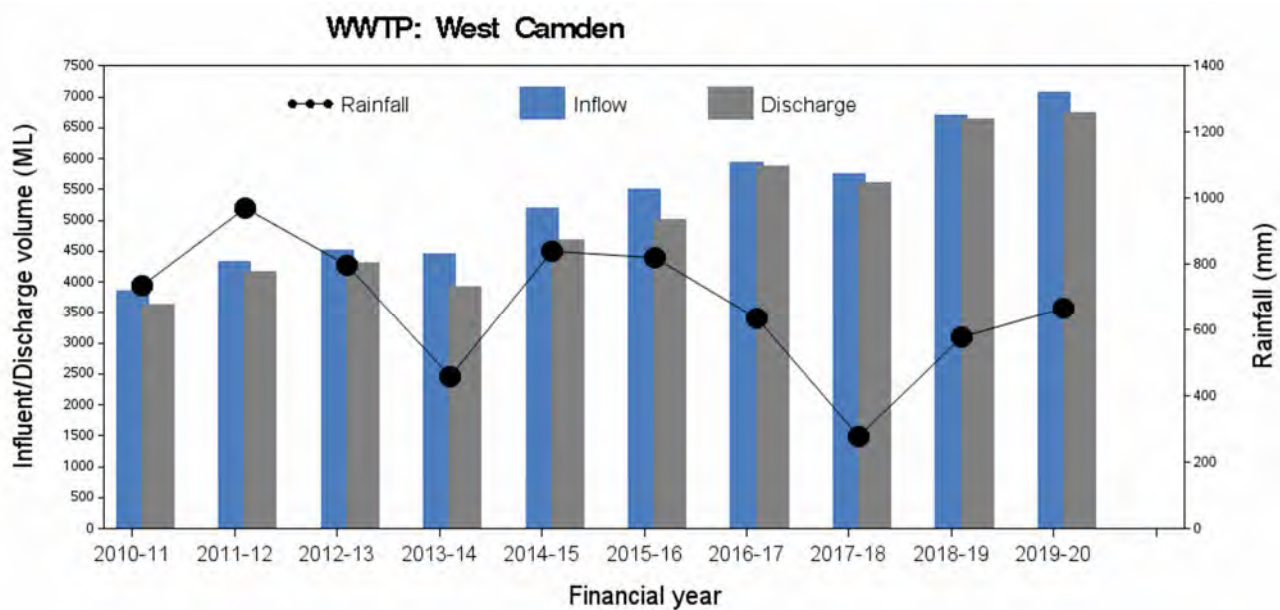


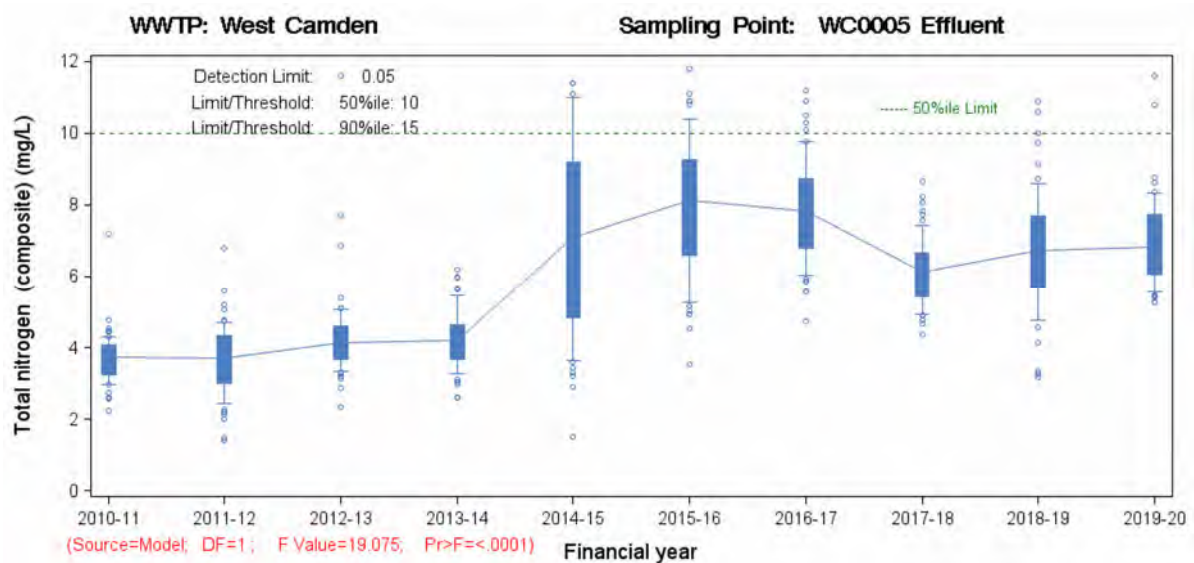
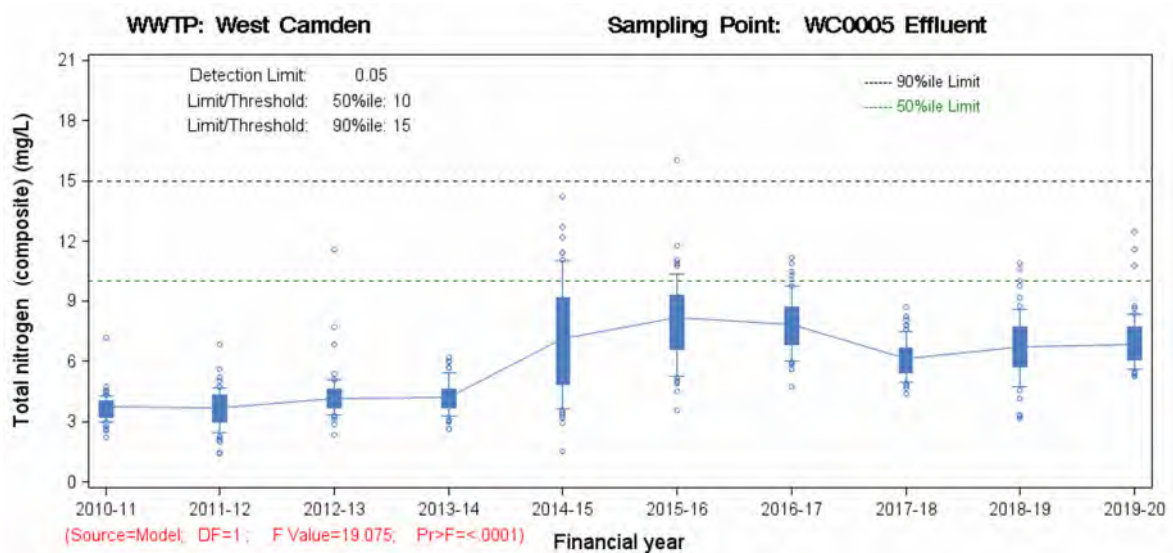
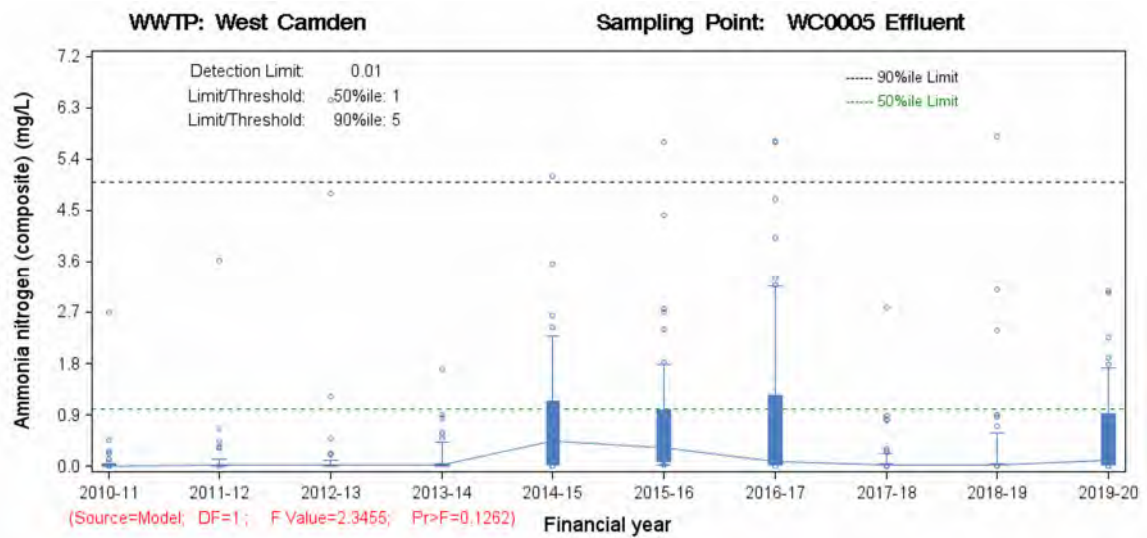
WWTP: Pictou

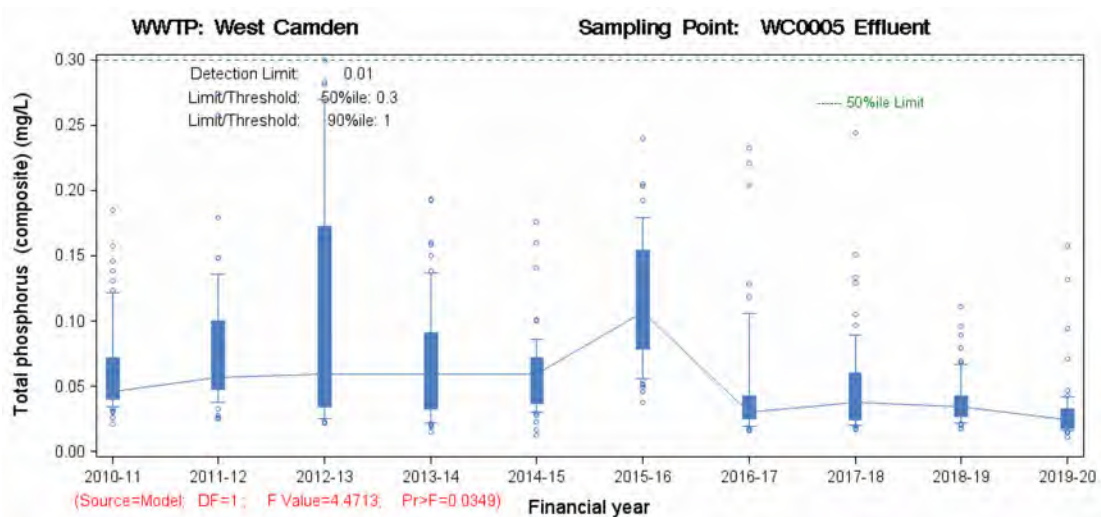
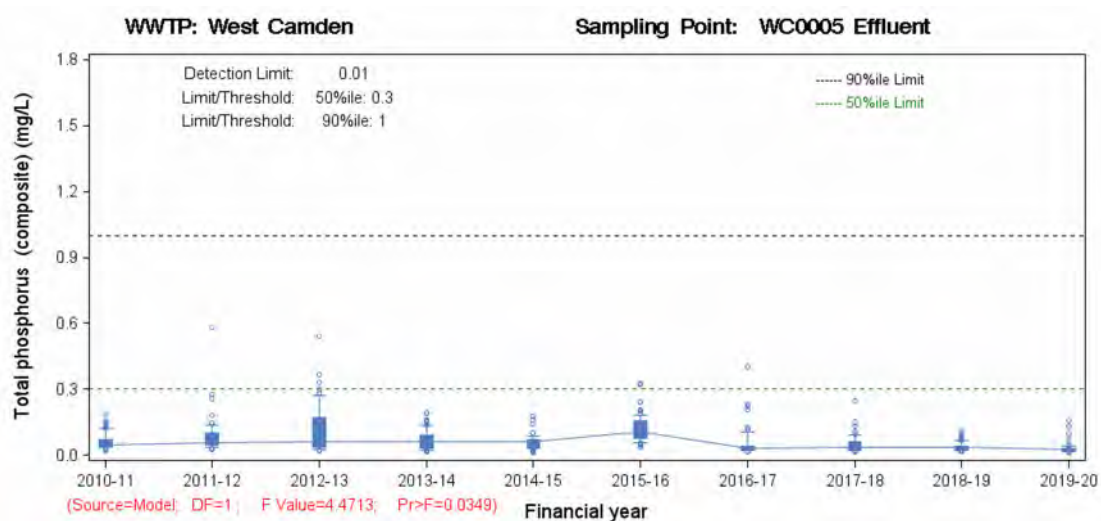


West Camden WWTP

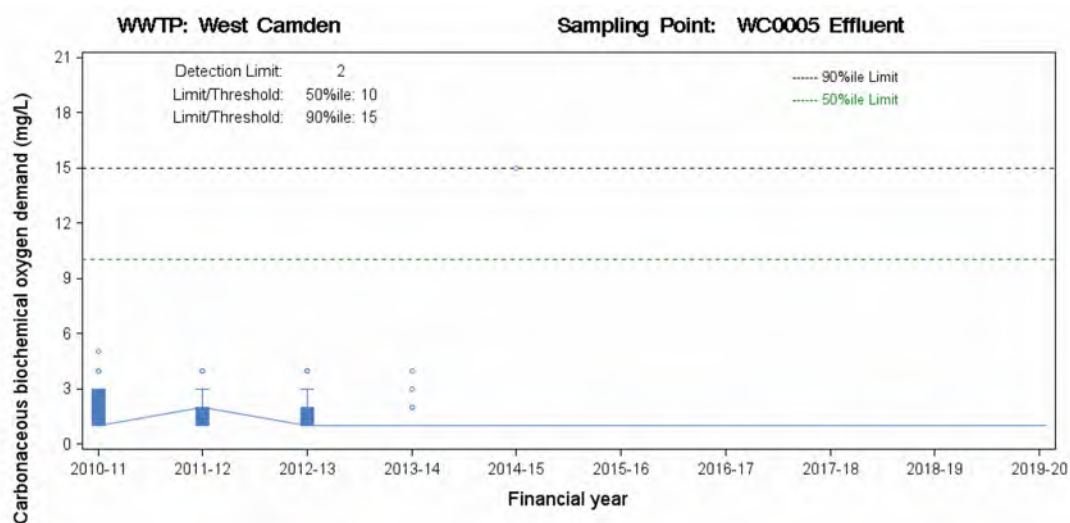
Discharge volume and rainfall







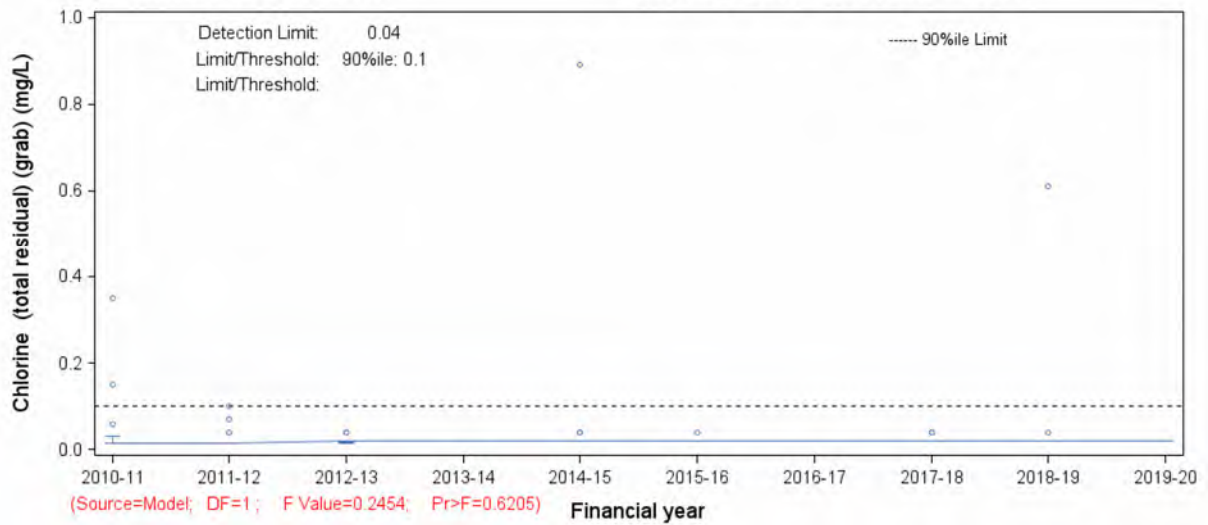
Discharge quality: Major conventional analytes



Note: 2019-20 data was compared with previous five years data (2014-2019) due to lab method change in 2014-15.
Statistical test was not conducted because >90% of results were below the detection limit.

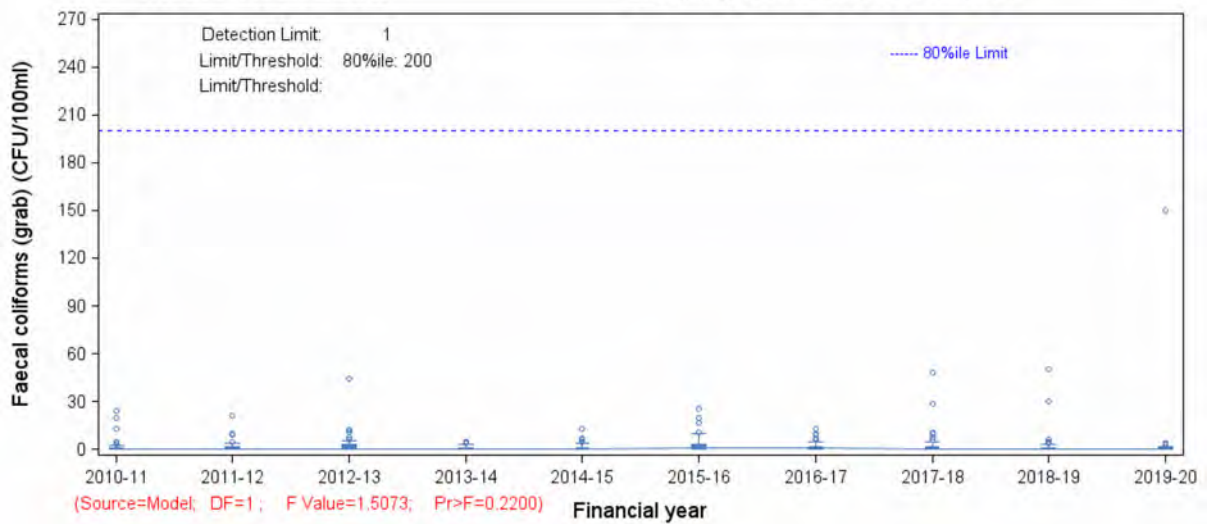
WWTP: West Camden

Sampling Point: WC0005 Effluent



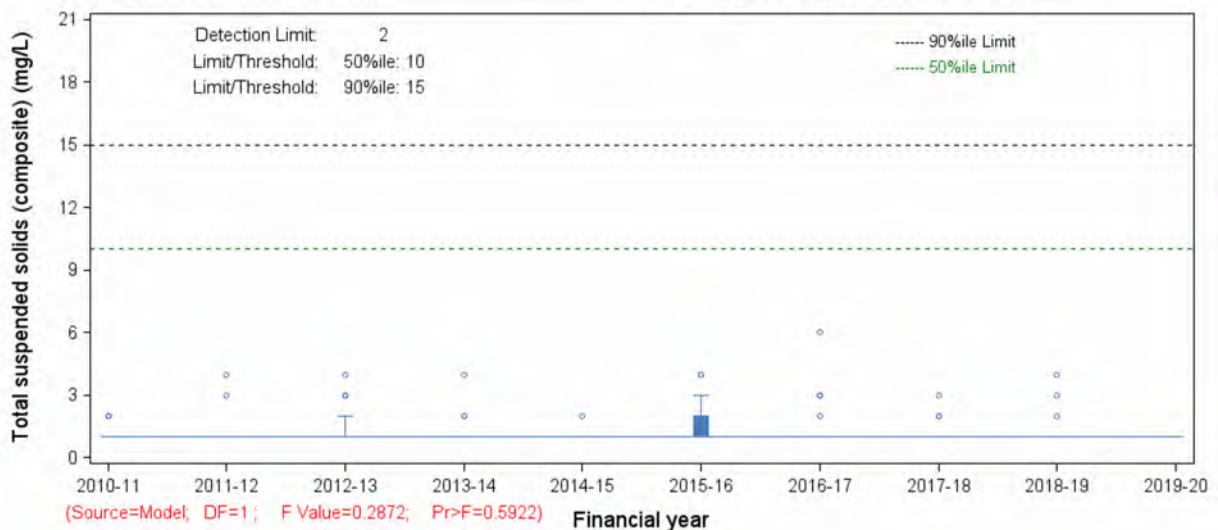
WWTP: West Camden

Sampling Point: WC0005 Effluent

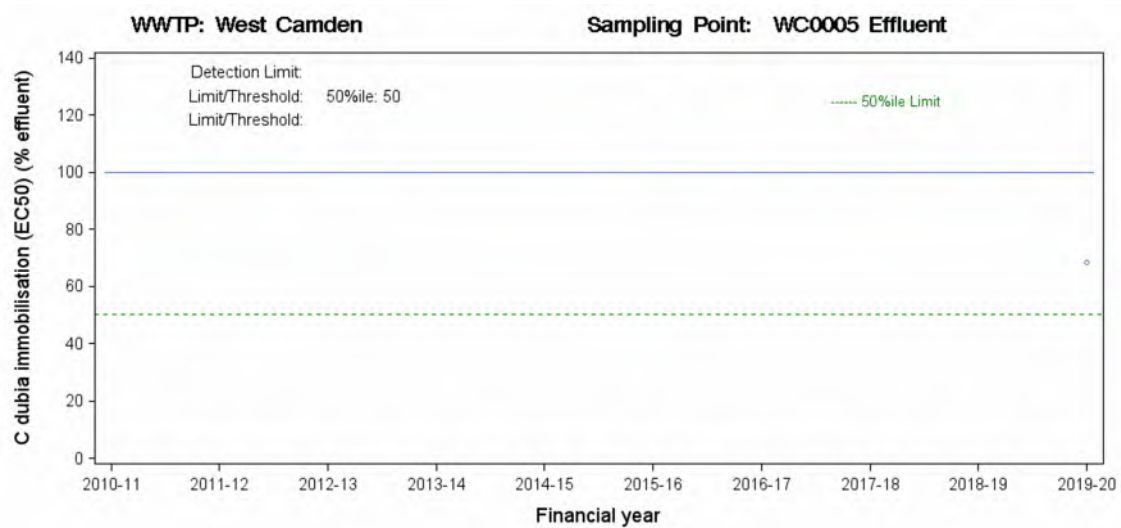


WWTP: West Camden

Sampling Point: WC0005 Effluent

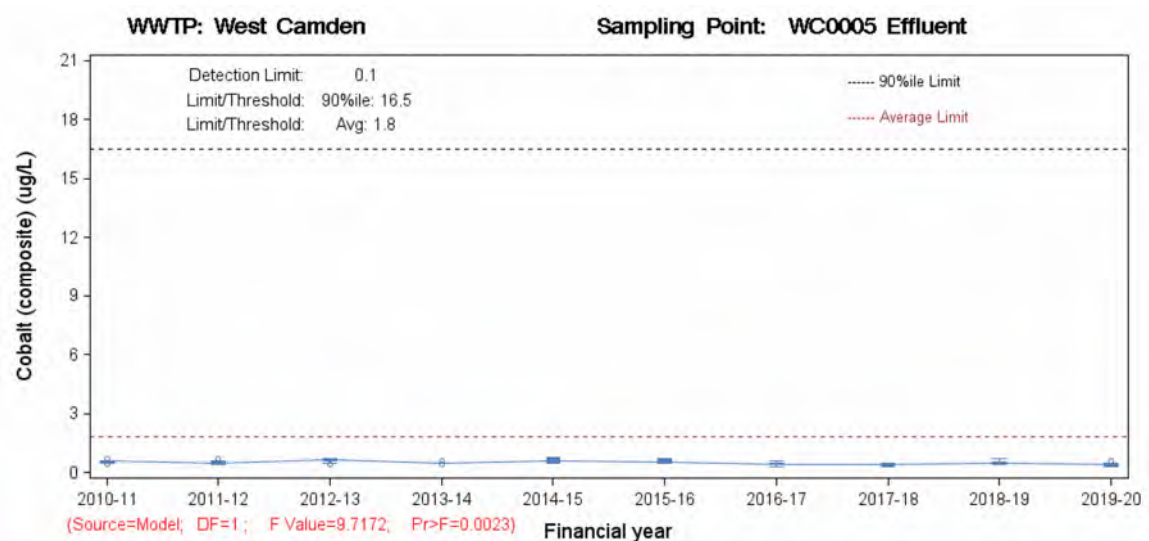
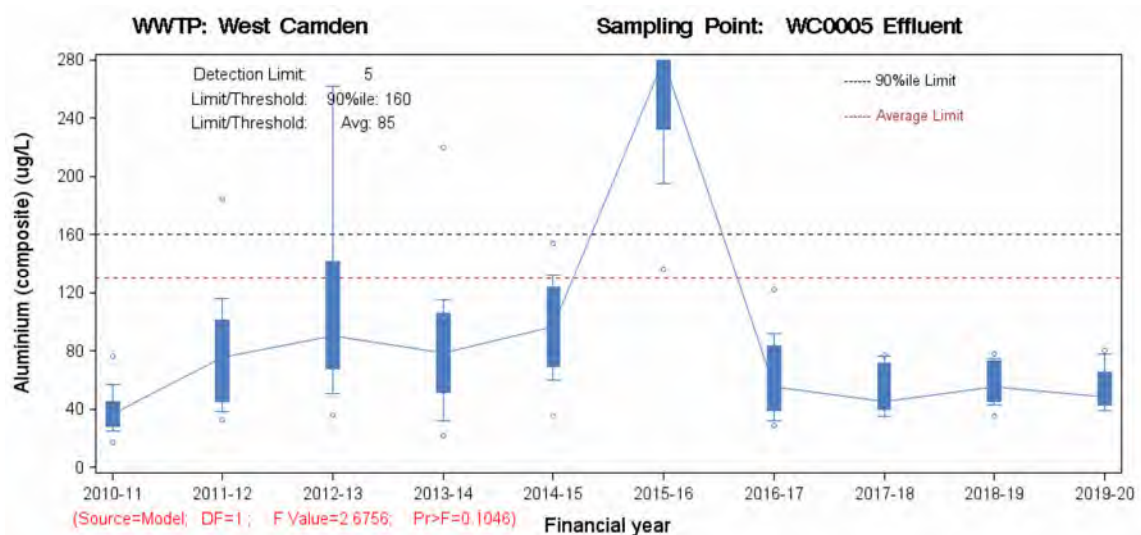


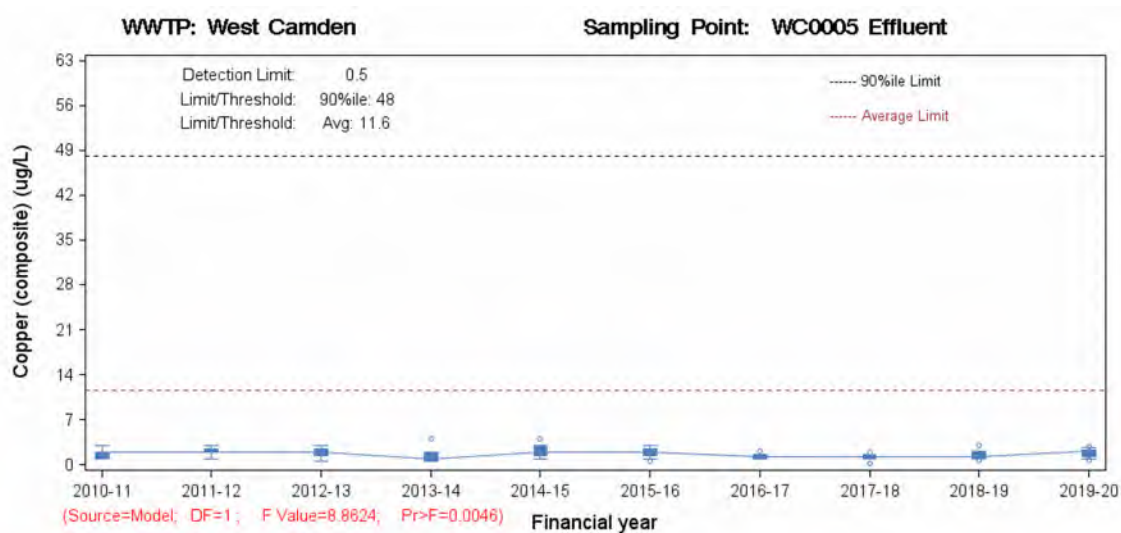
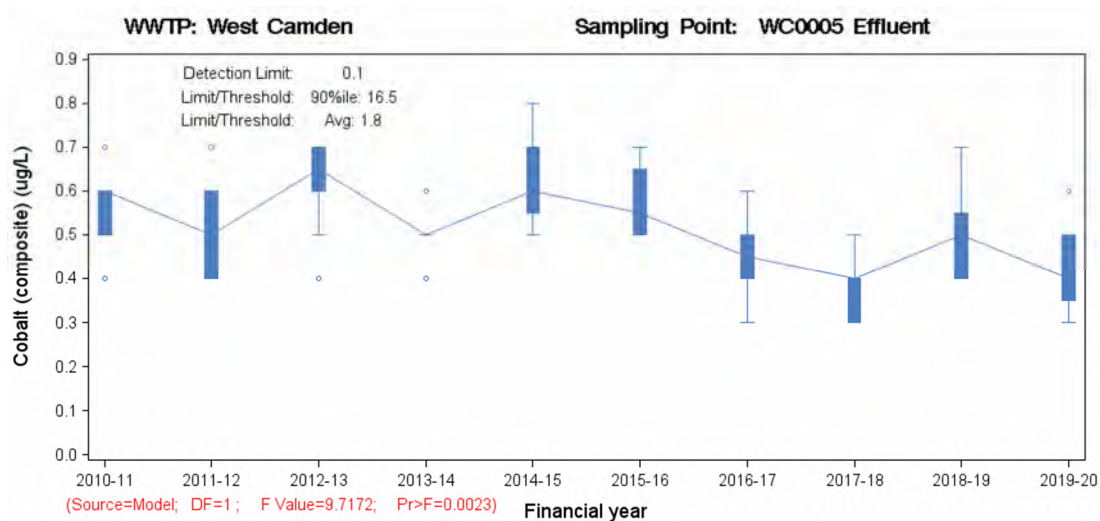
Discharge quality: Toxicity



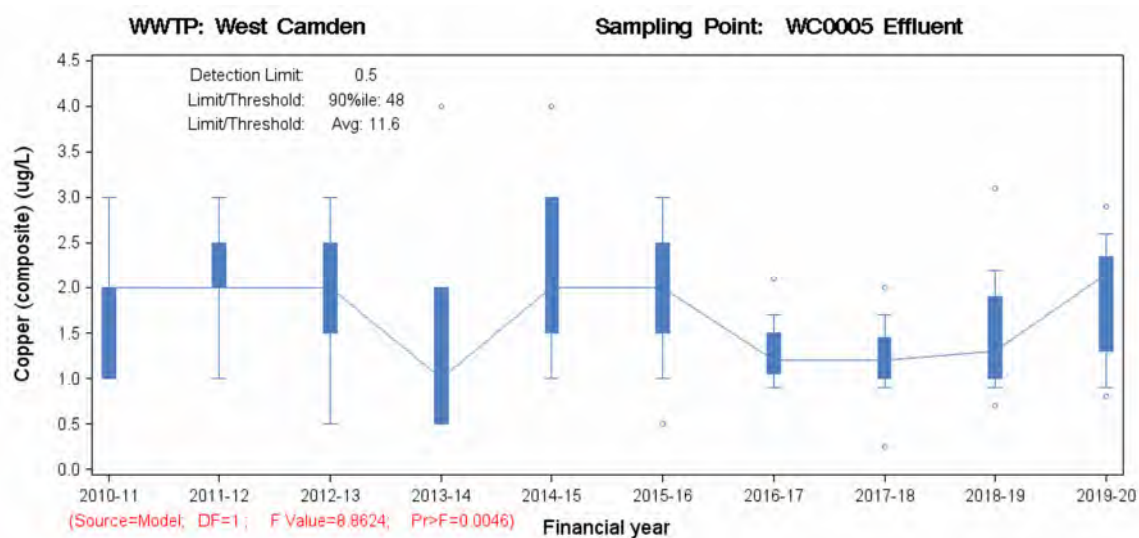
Note: Statistical test was not conducted because >90% of results were recorded at 100% survival for *Ceriodaphnia dubia*.

Discharge quality: Trace metals

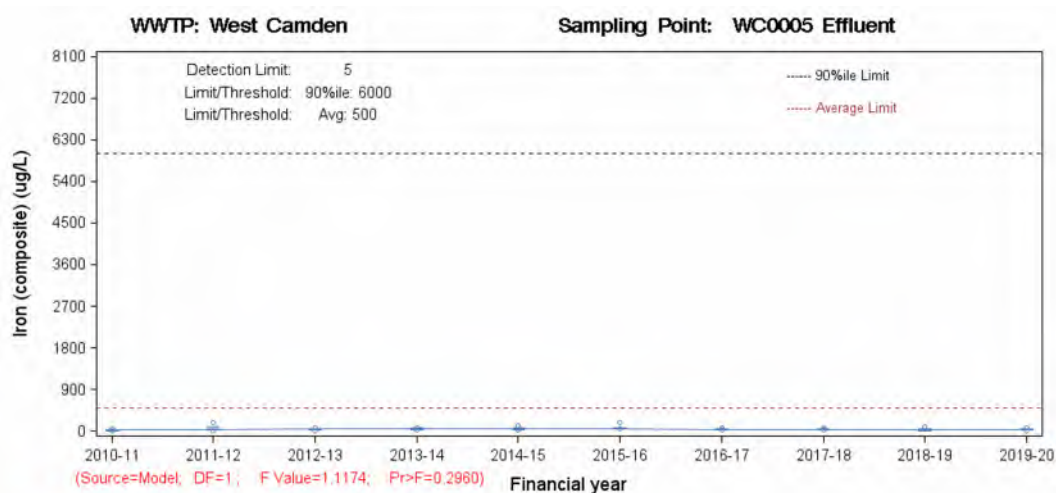




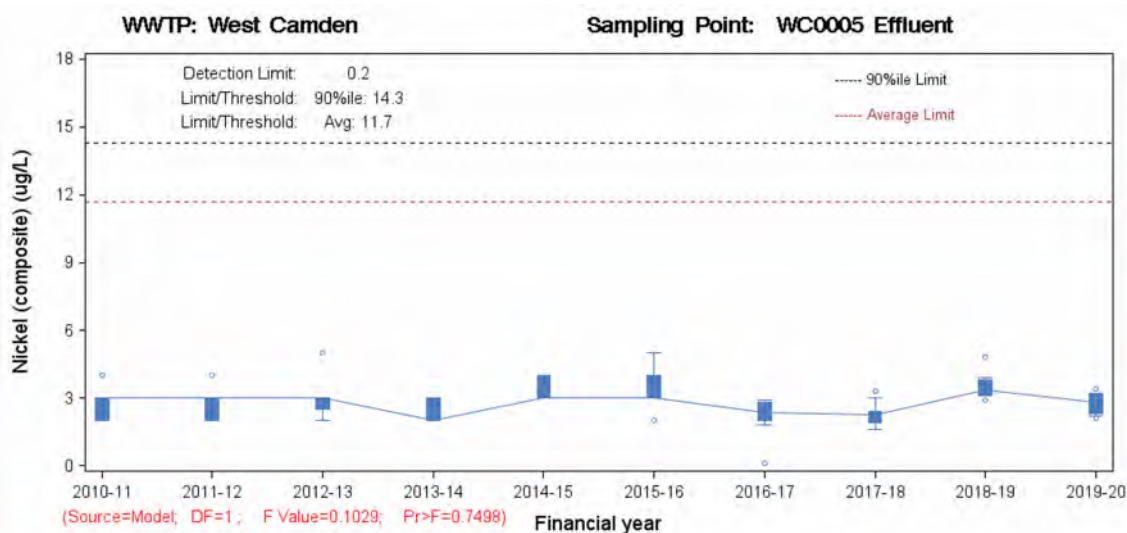
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.



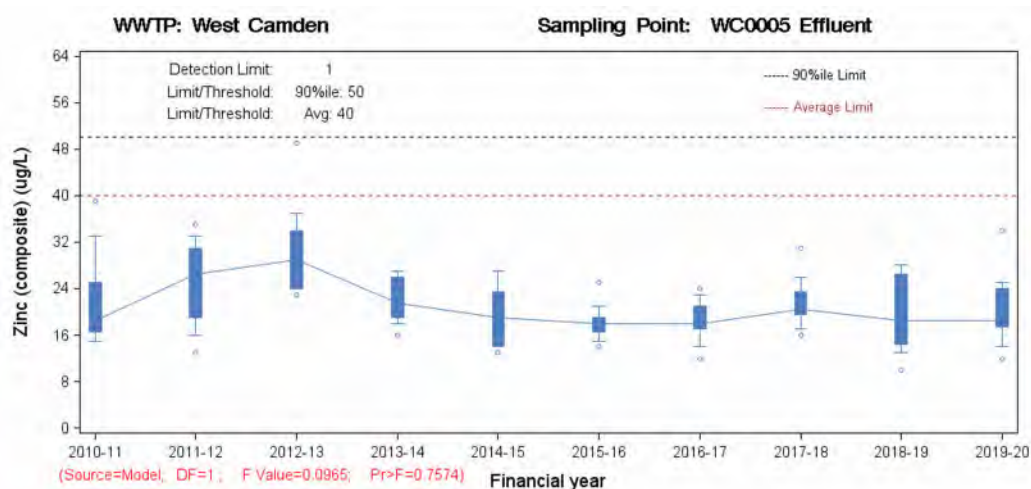
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.



Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

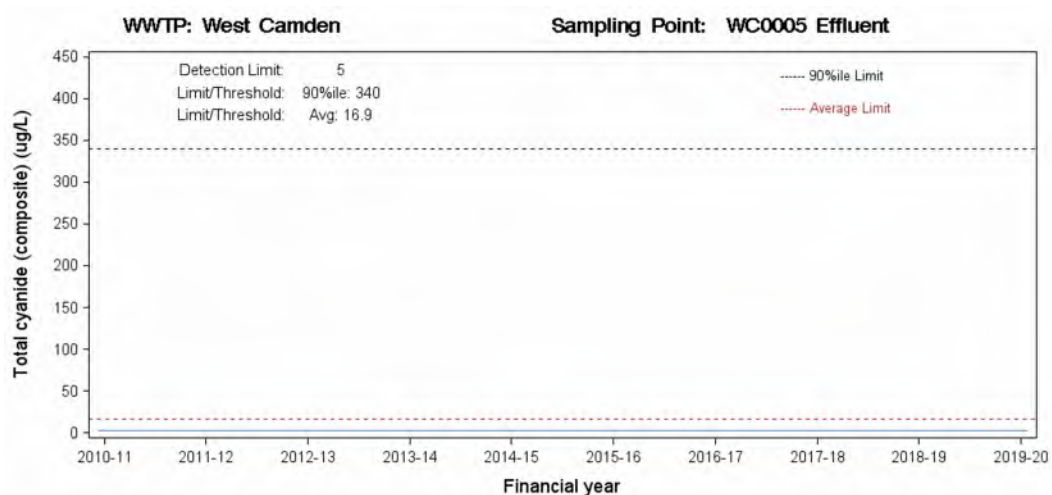


Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

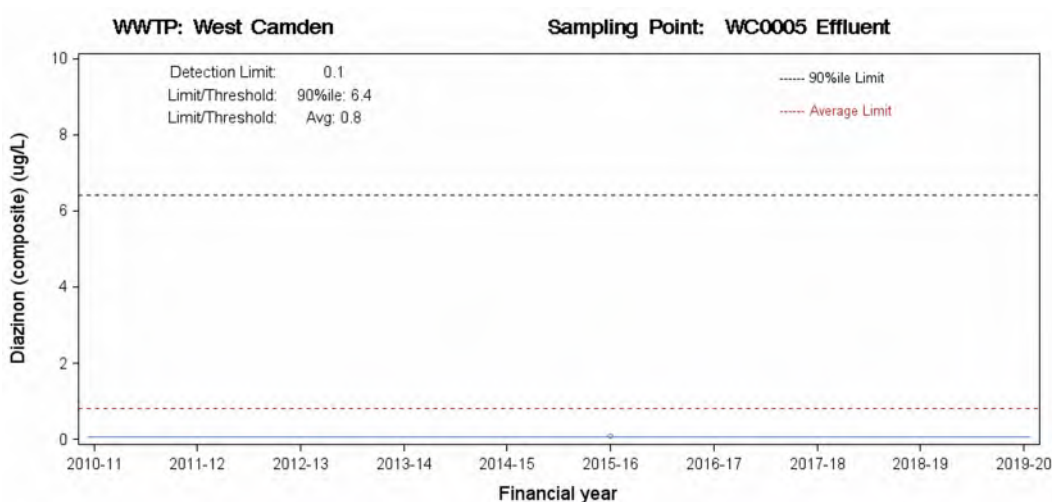


Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

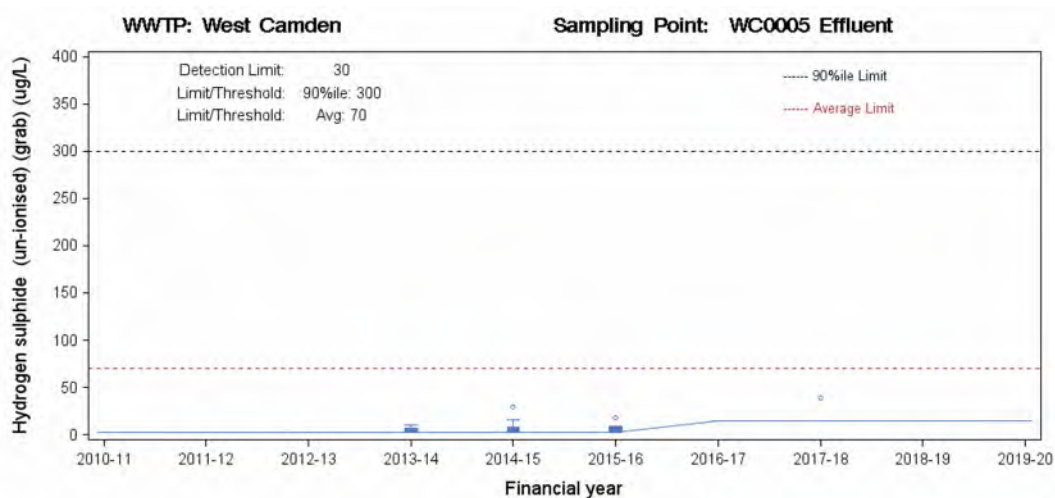
Discharge quality: Other chemicals and organics (including pesticides)



Note: Statistical test was not conducted because >90% of results were below the detection limit.

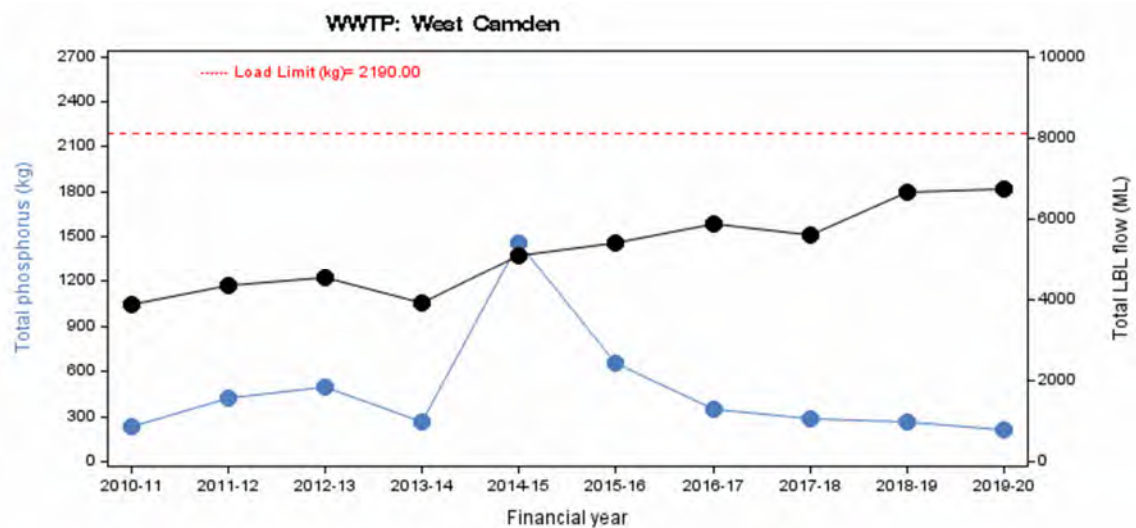
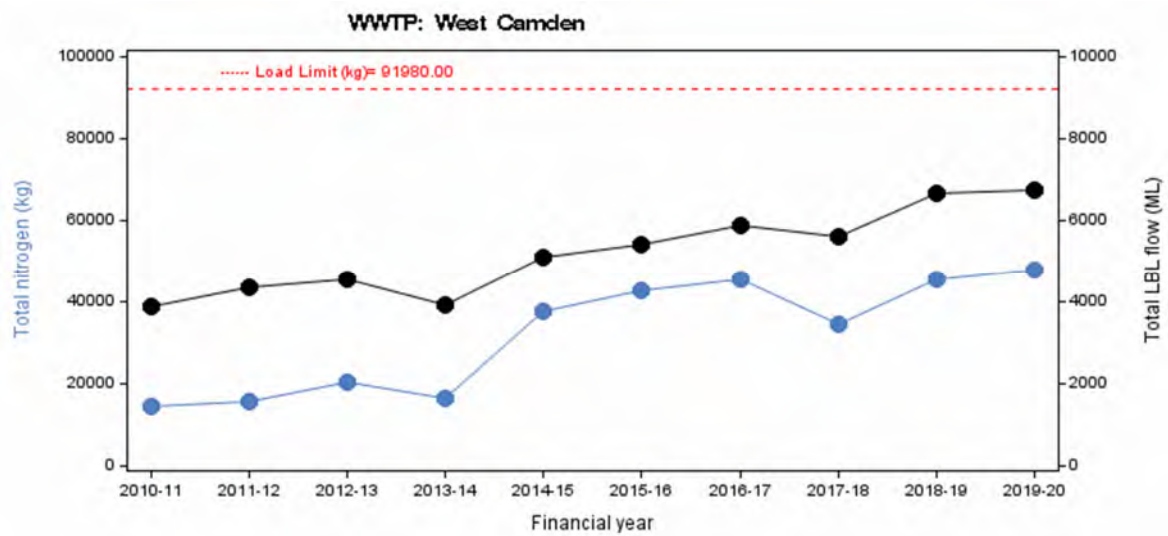


Note: Statistical test was not conducted because >90% of results were below the detection limit.

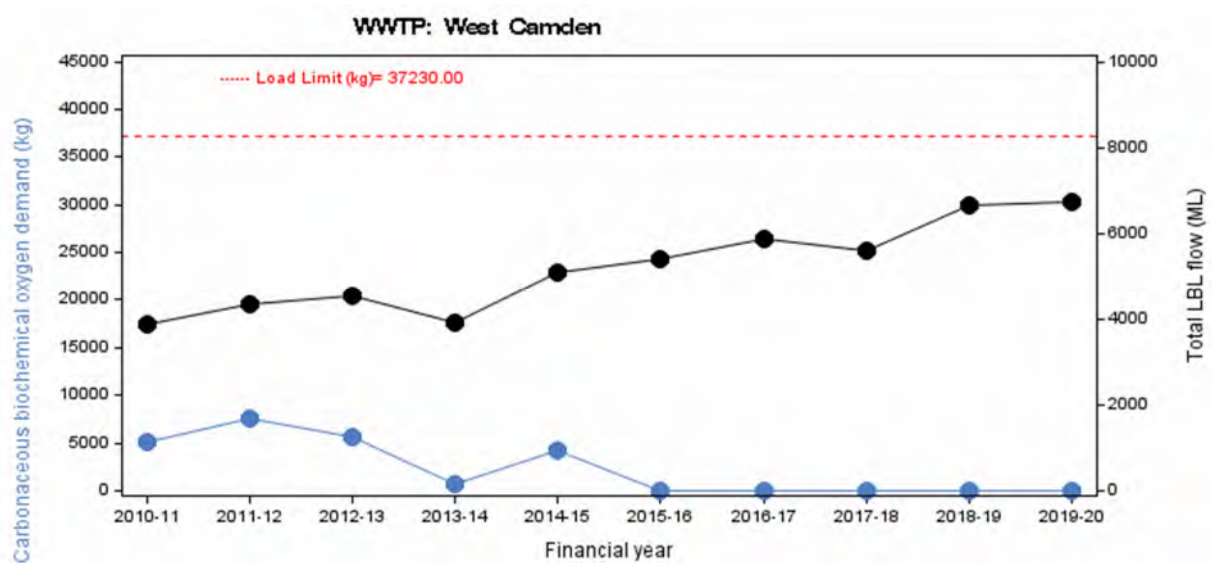


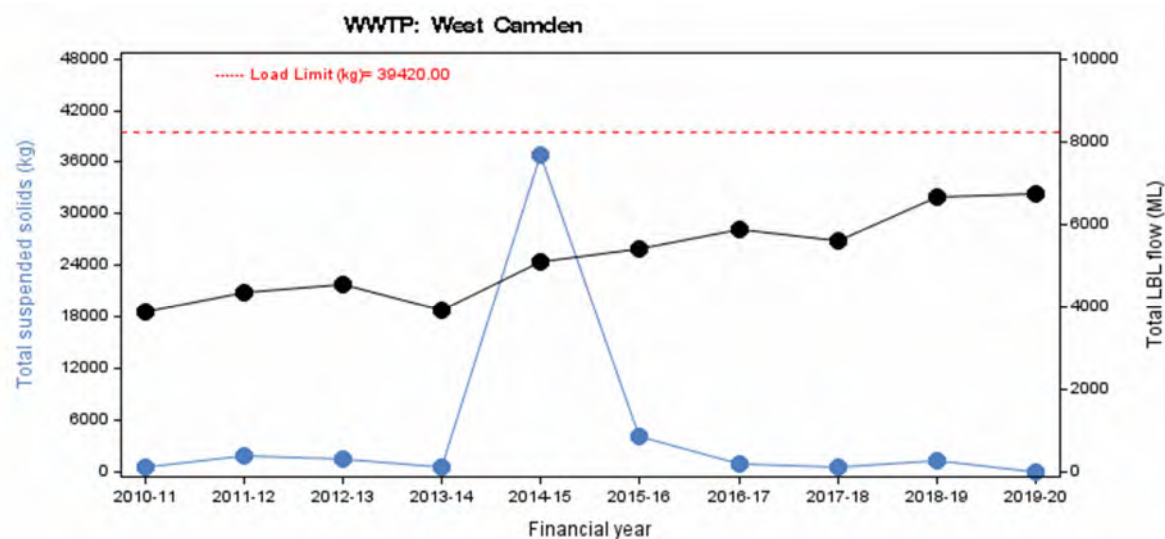
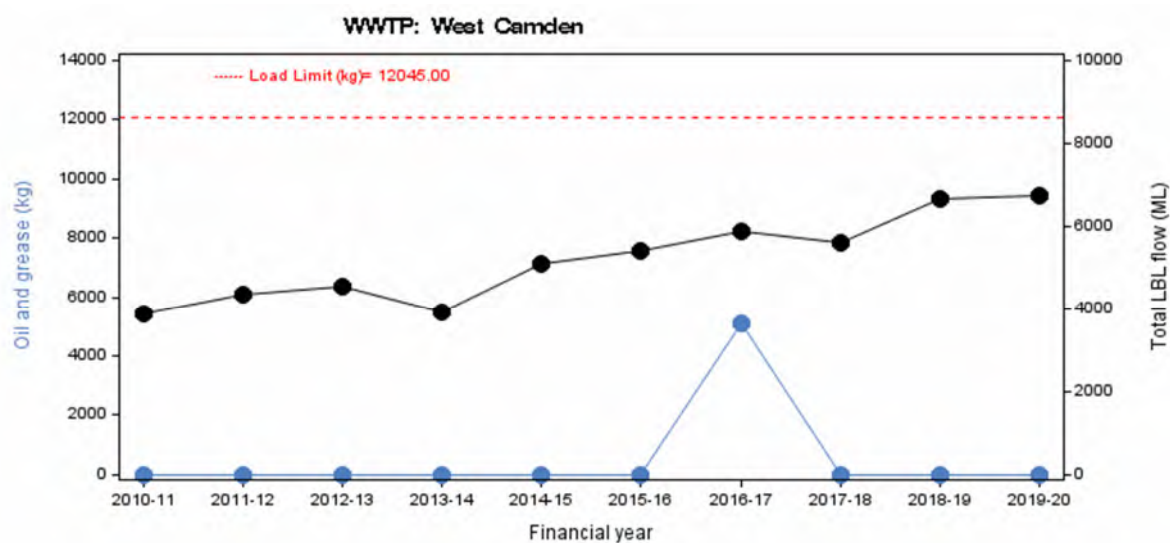
Note: 2019-20 data was compared with previous three years data (2016-2019) due to lab method change in 2016-17.
Statistical test was not conducted because >90% of results were below the detection limit.

Discharge load: Nutrients



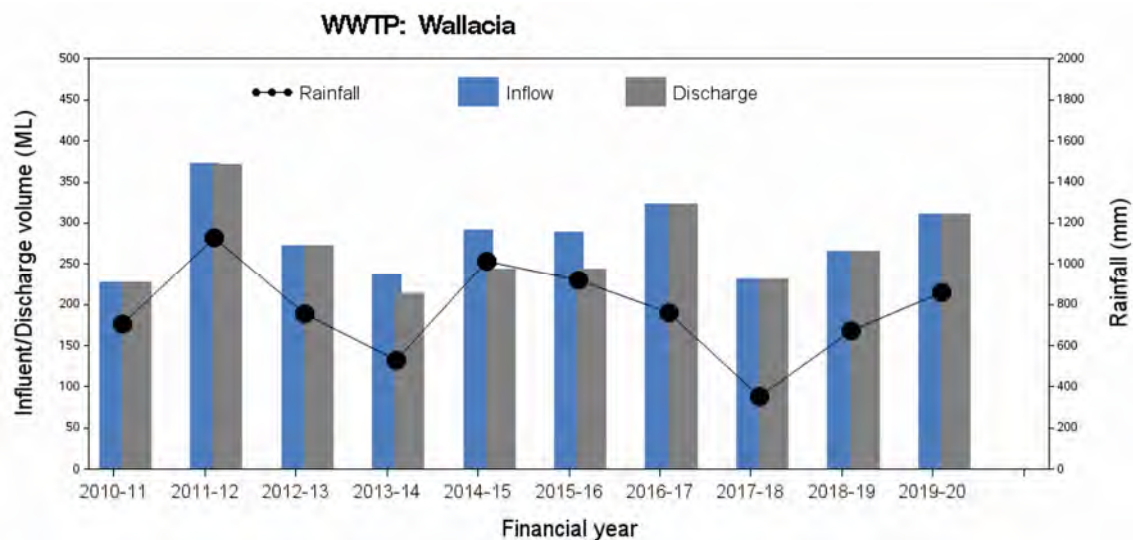
Discharge load: Major conventional analytes



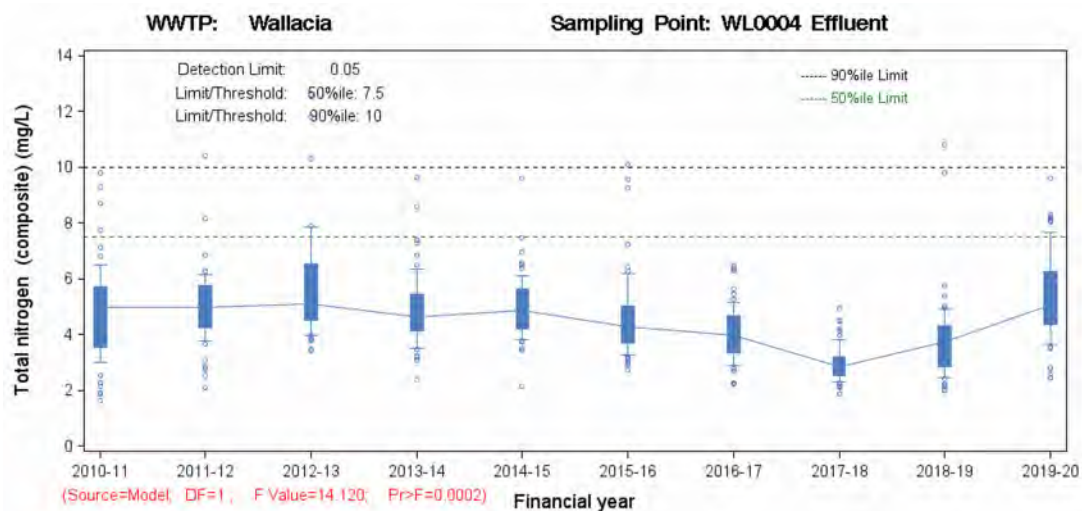
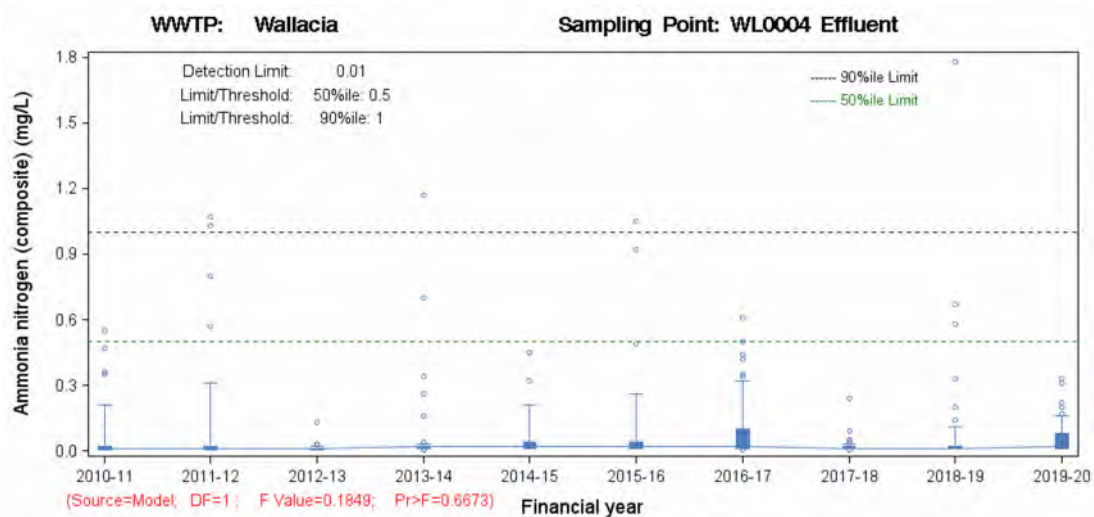


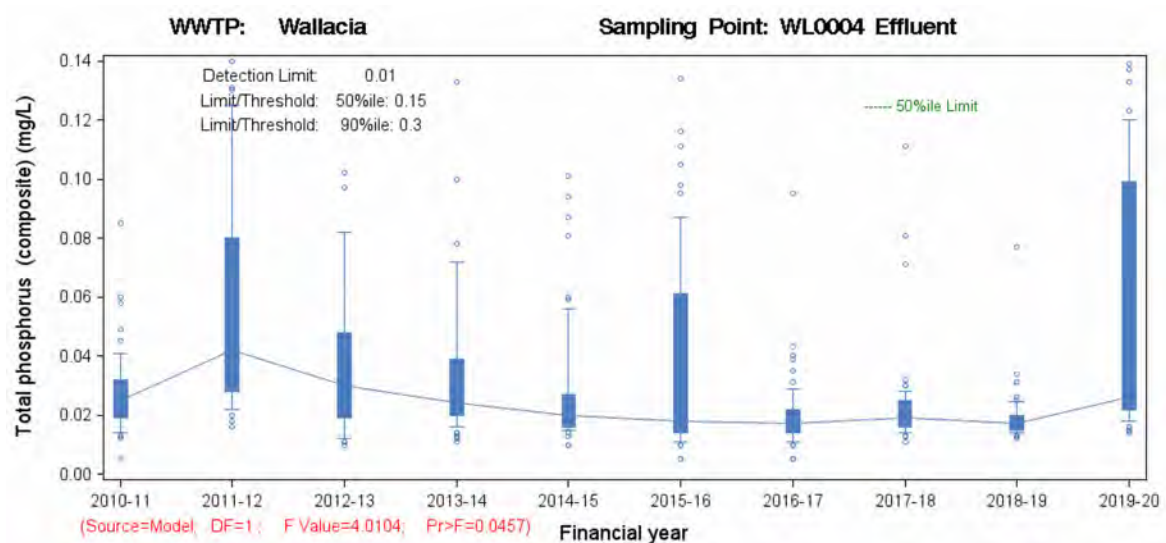
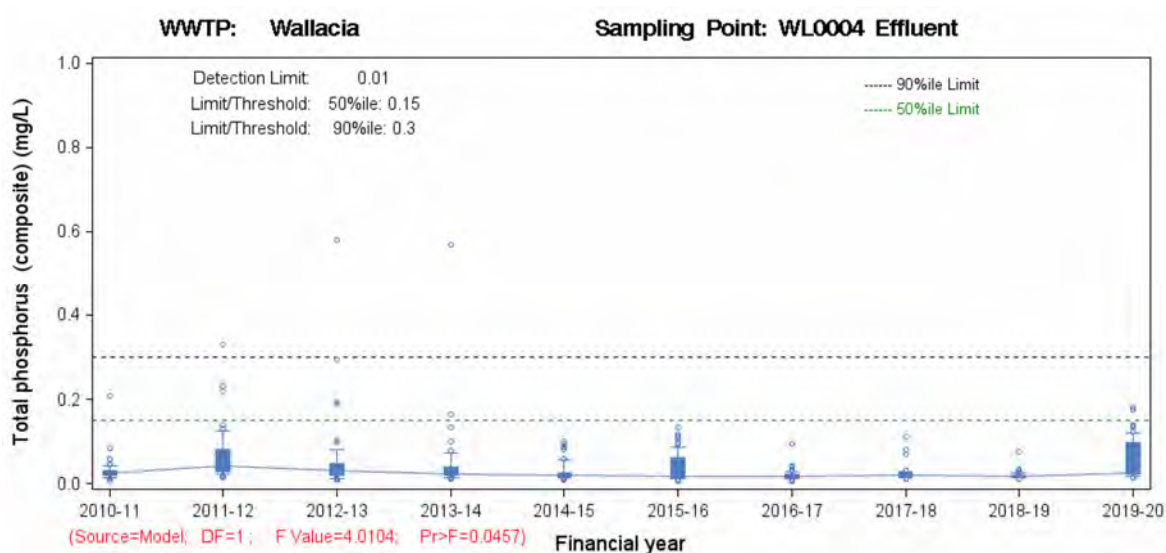
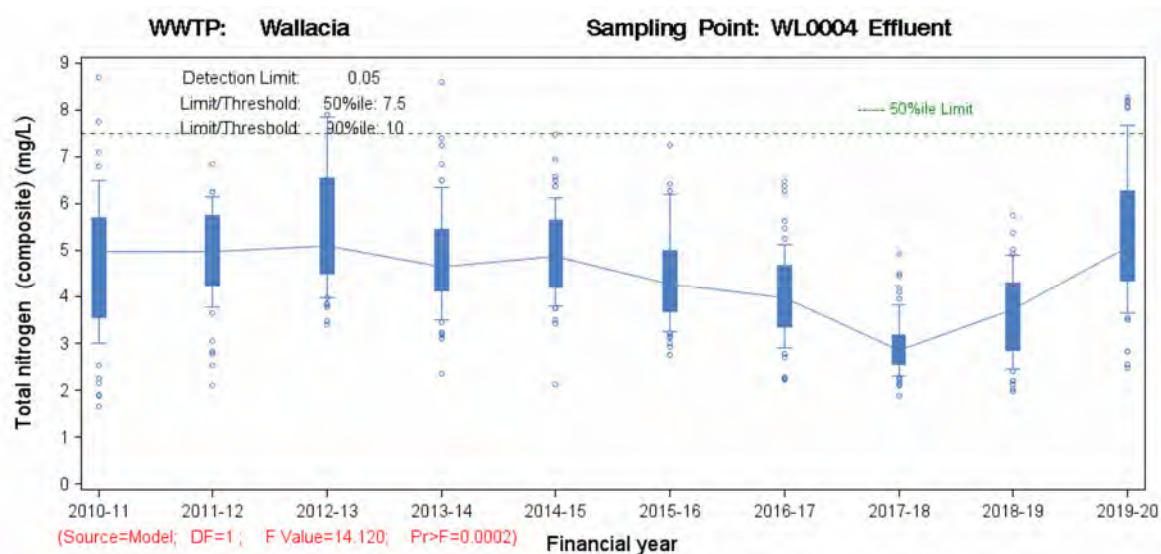
Wallacia WWTP

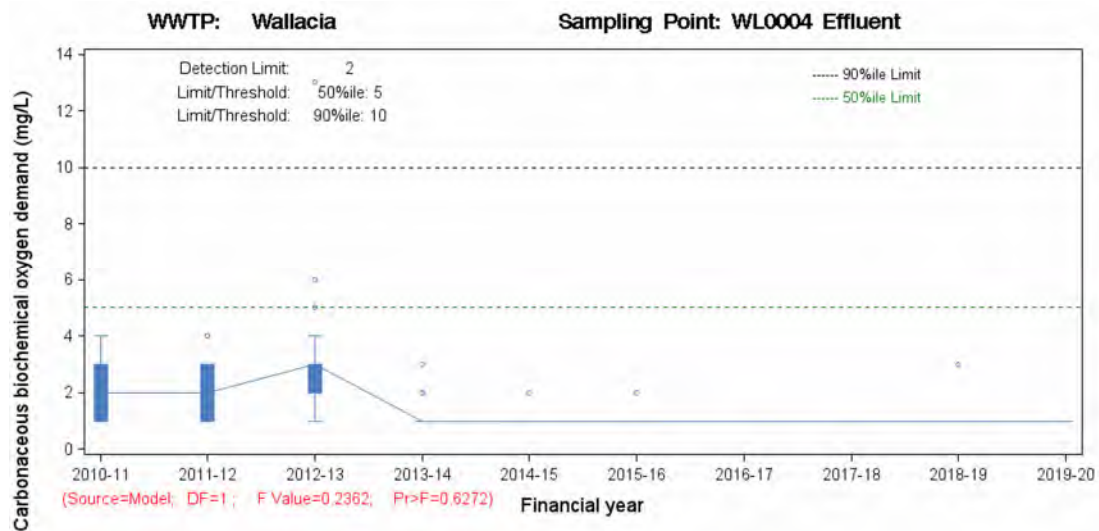
Discharge volume and rainfall



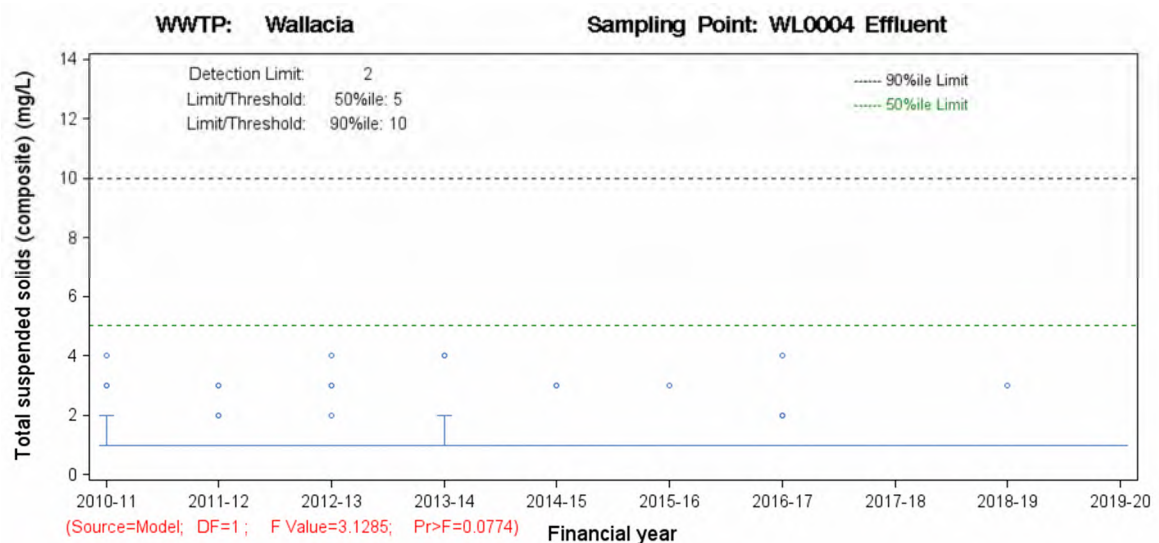
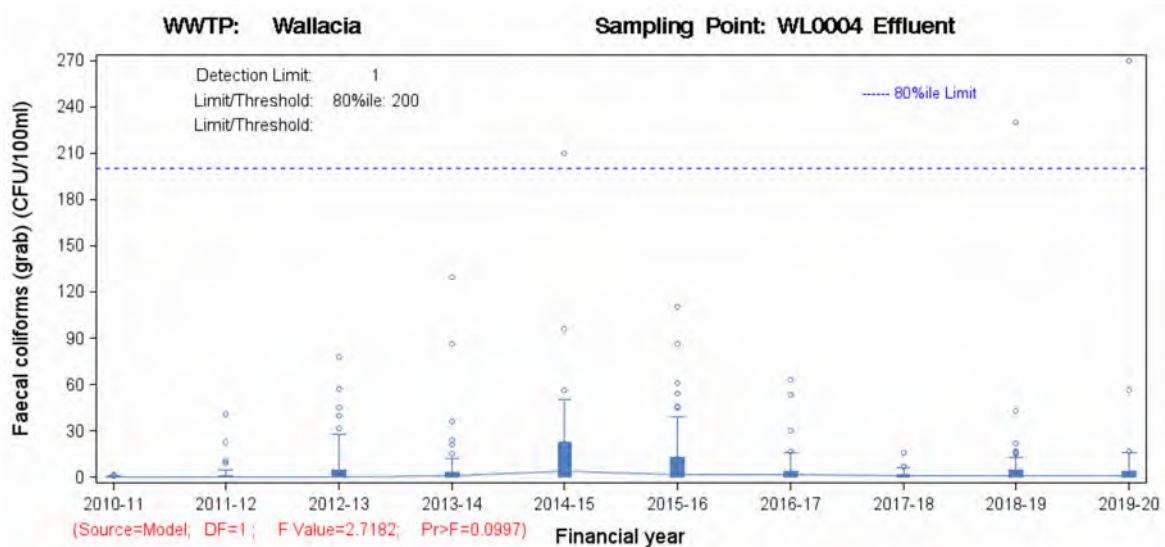
Discharge quality: Nutrients



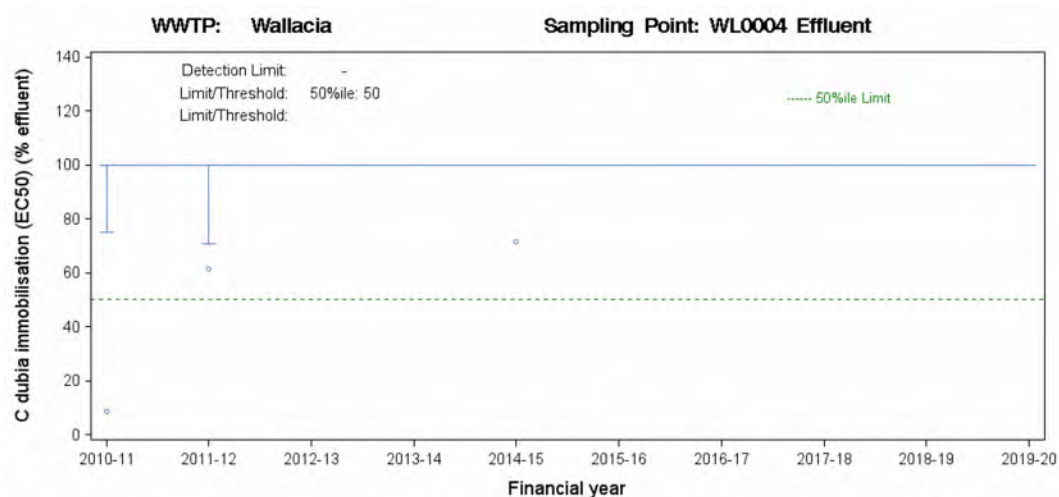




Note: Statistical test was based on 2019-20 data with previous five years data (2014-2019) due to lab method change in 2014-15.

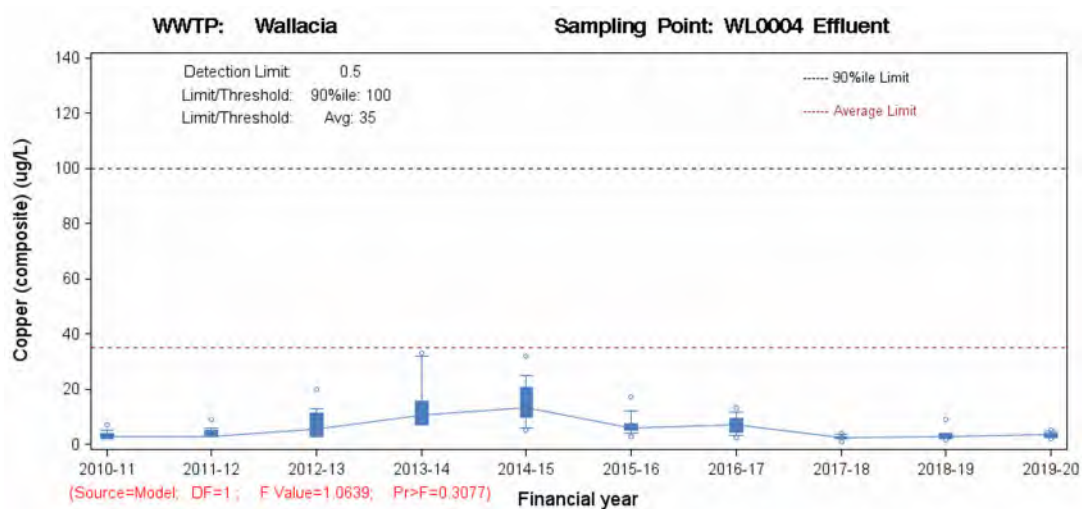
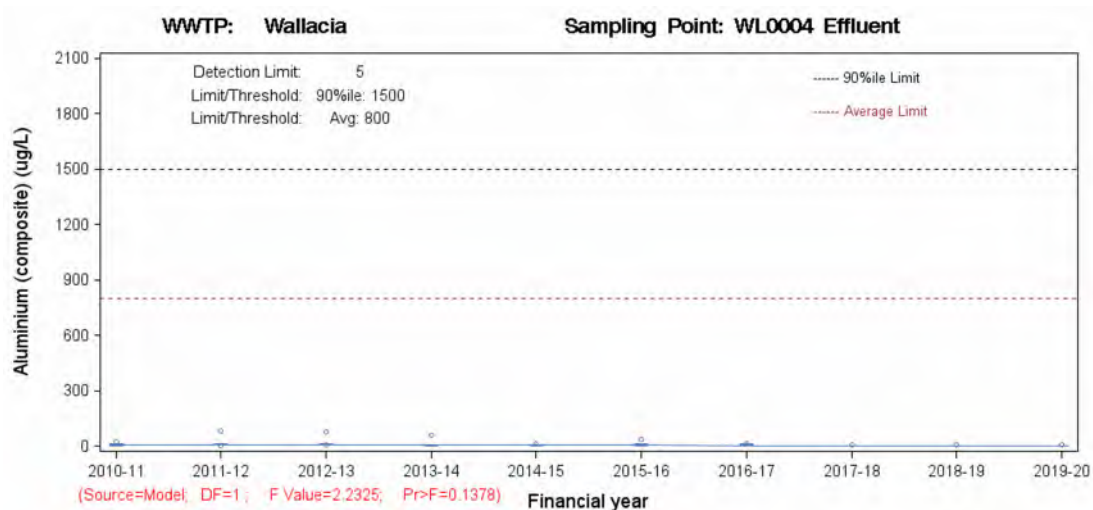


Discharge quality: Toxicity

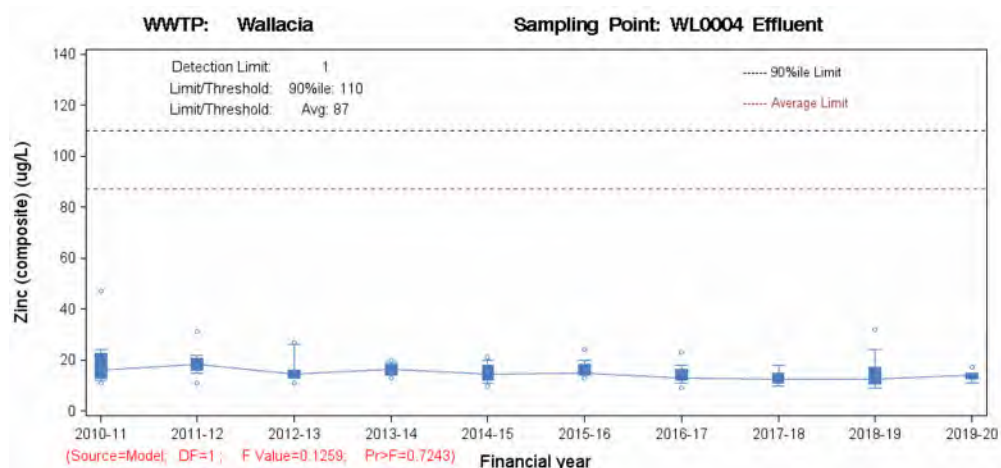


Note: Statistical test was not conducted because >90% of results were recorded at 100% survival for *Ceriodaphnia dubia*

Discharge quality: Trace metals

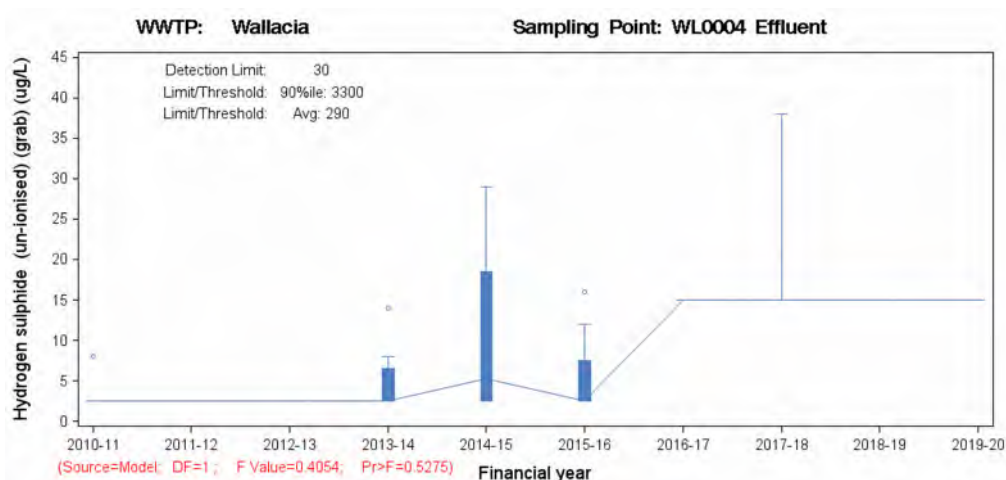


Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

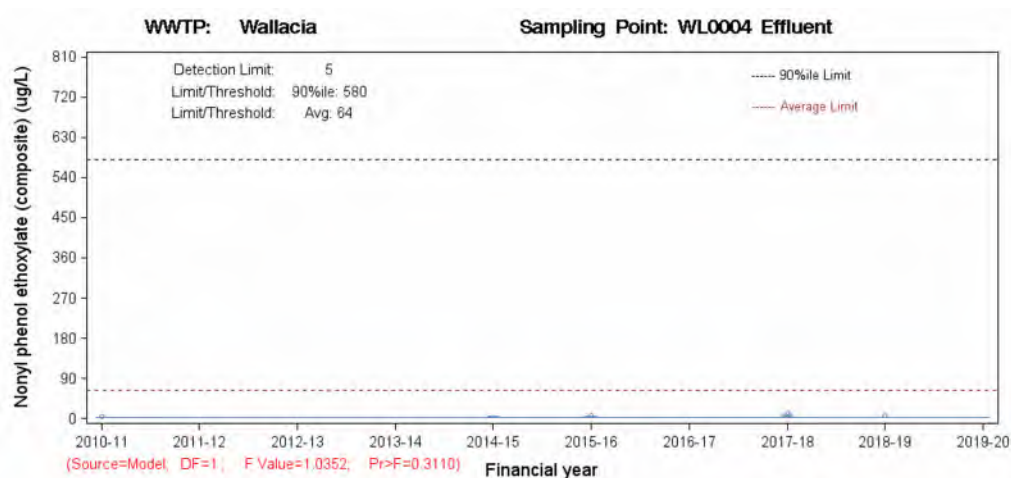


Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

Discharge quality: Other chemicals and organics (including pesticides)

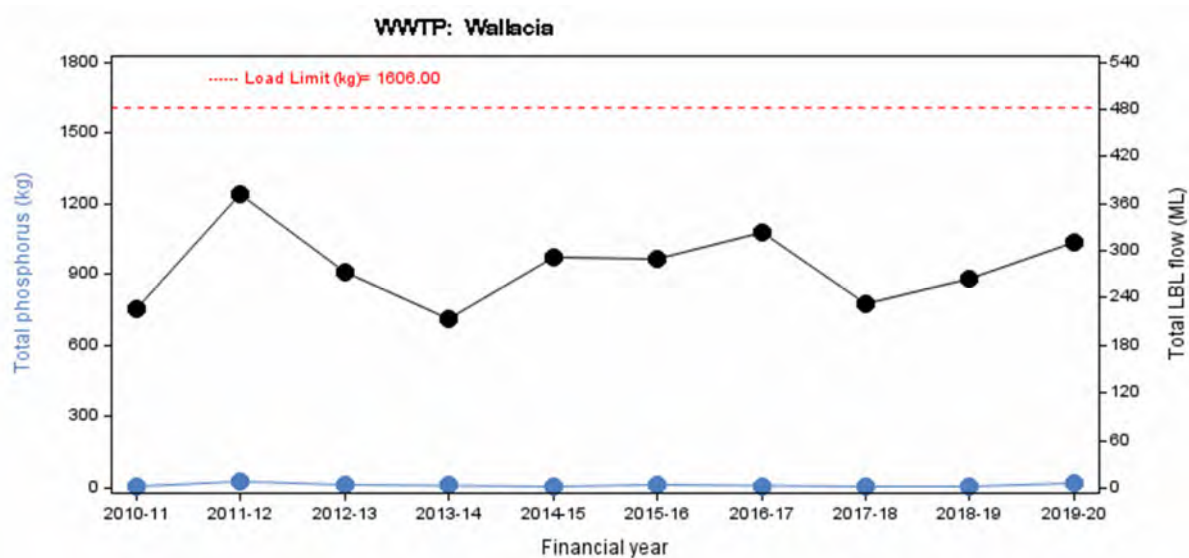
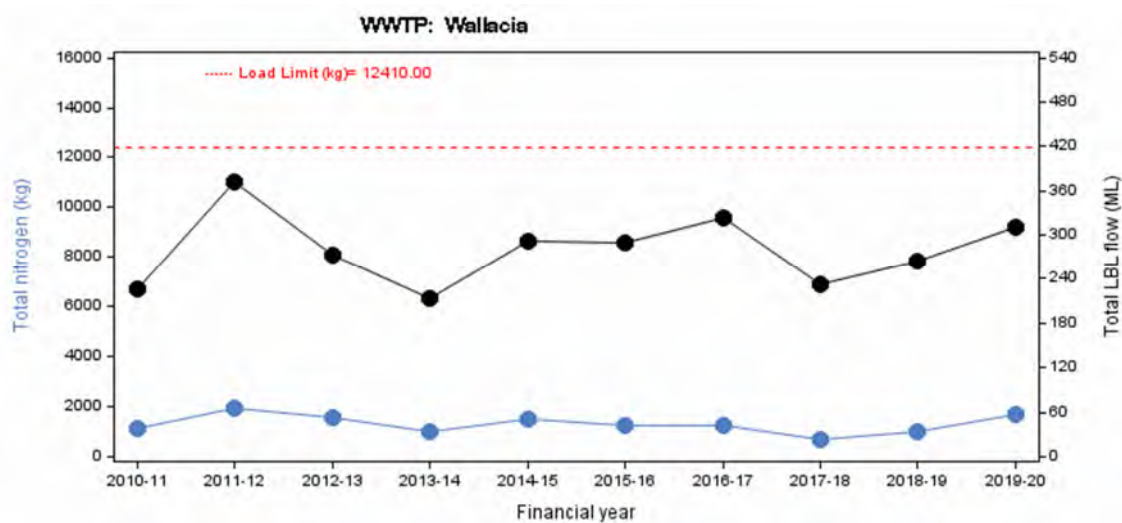


Note: 2019-20 data was compared with previous three years data (2016-2019) due to lab method change in 2016-17.

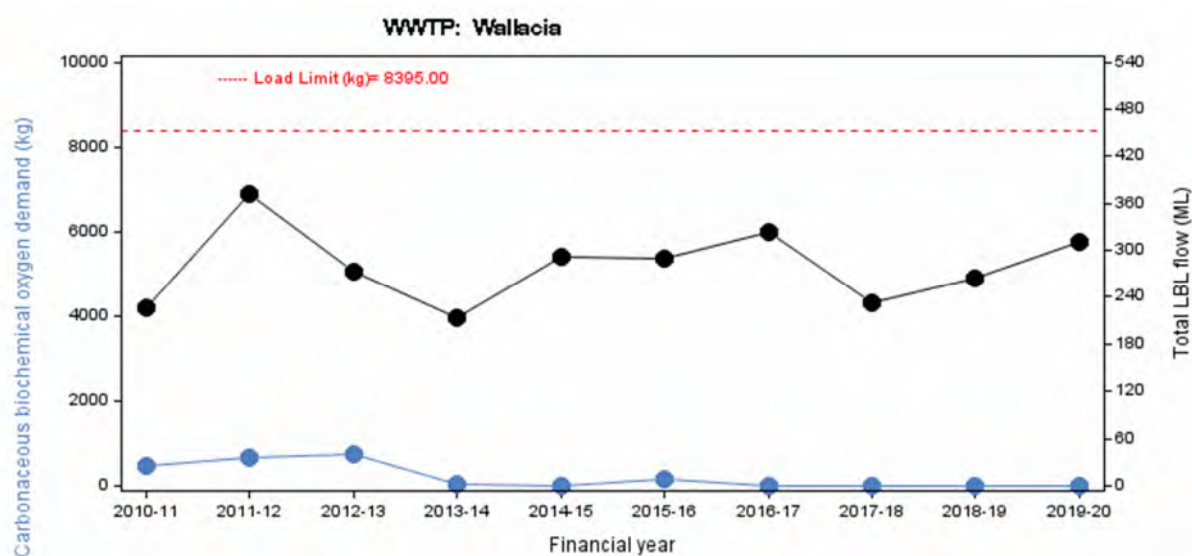


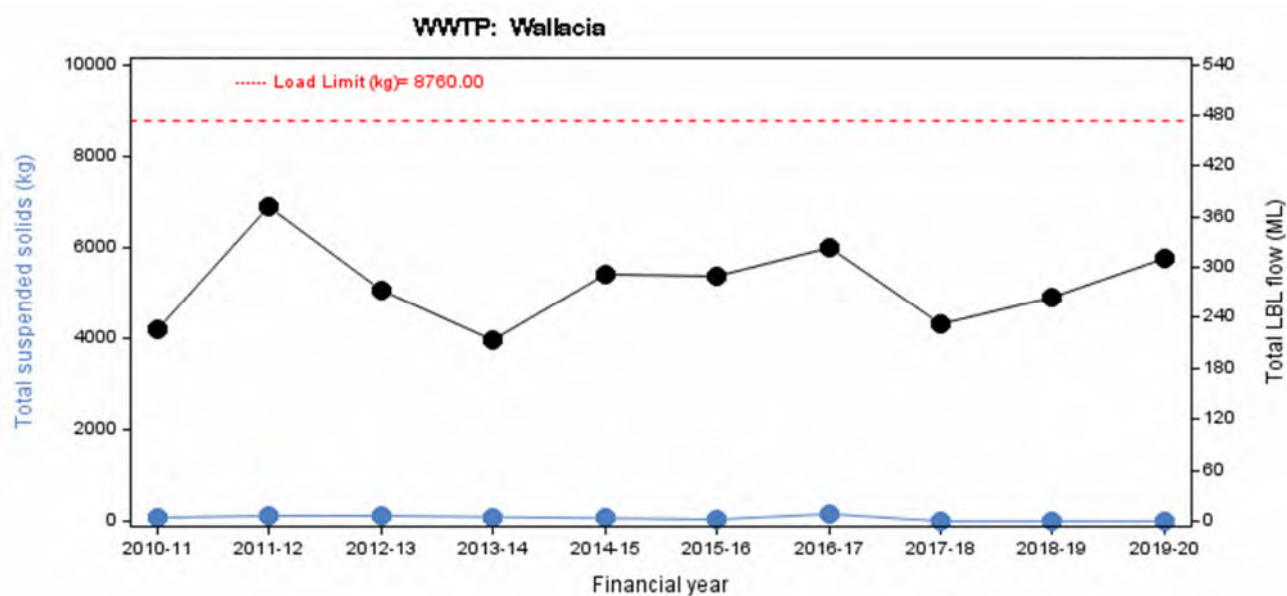
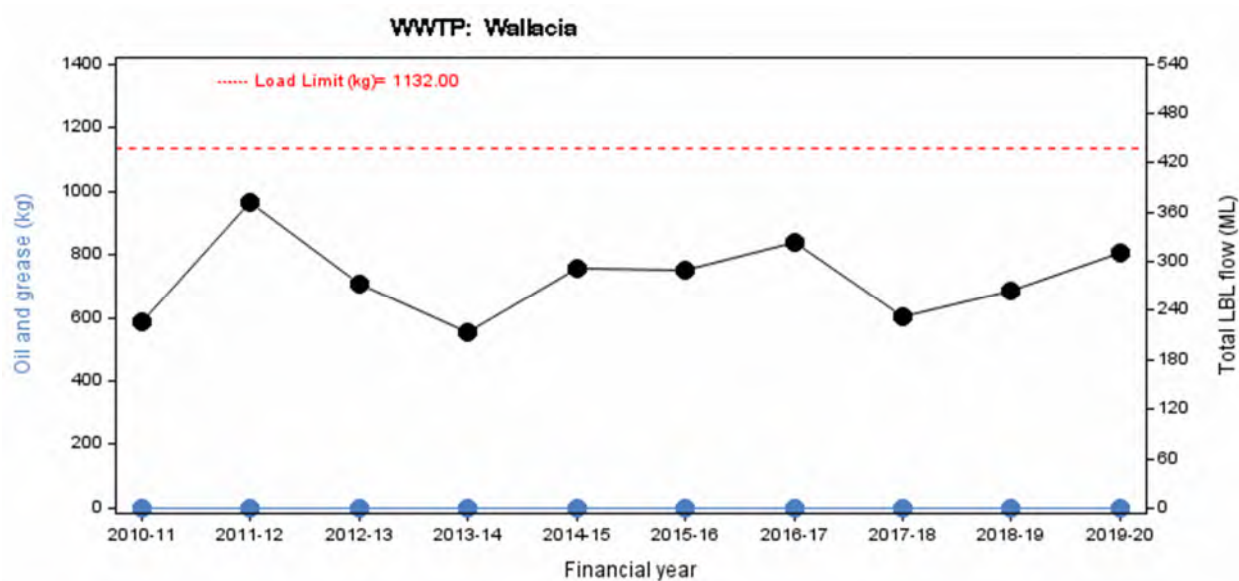
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

Discharge load: Nutrients



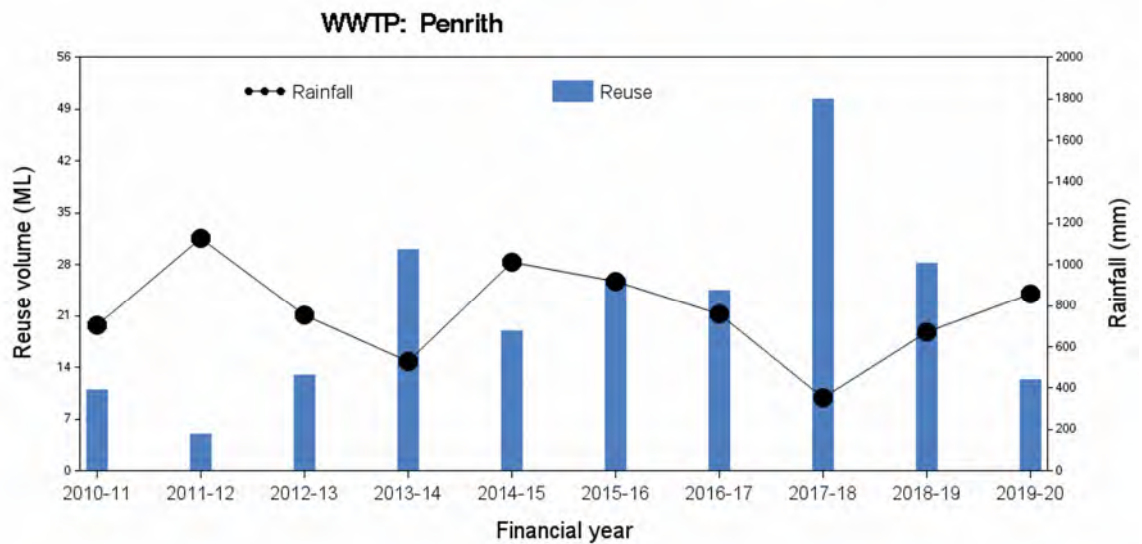
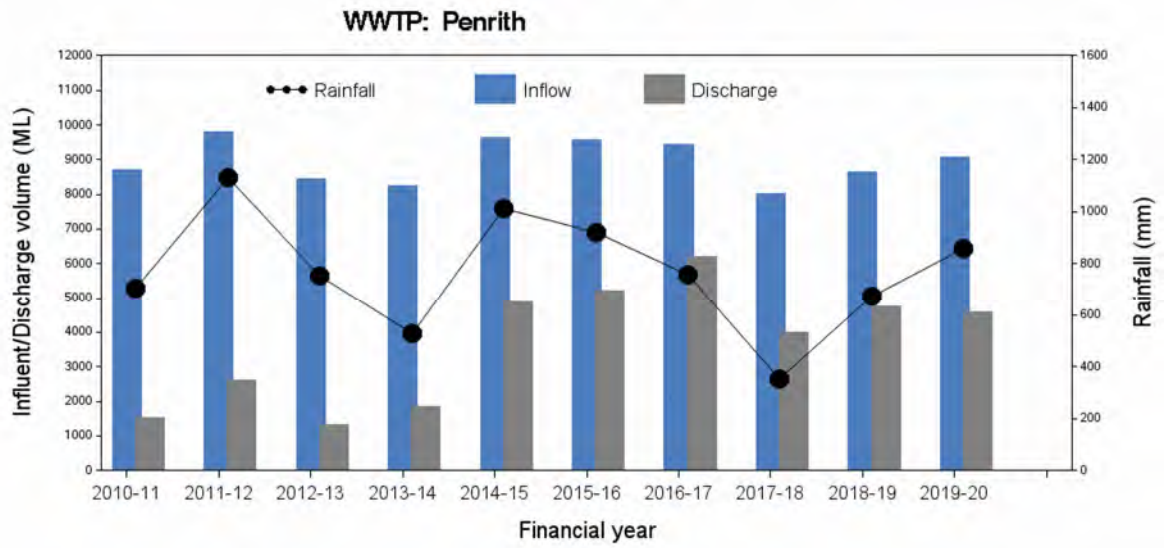
Discharge load: Major conventional analytes

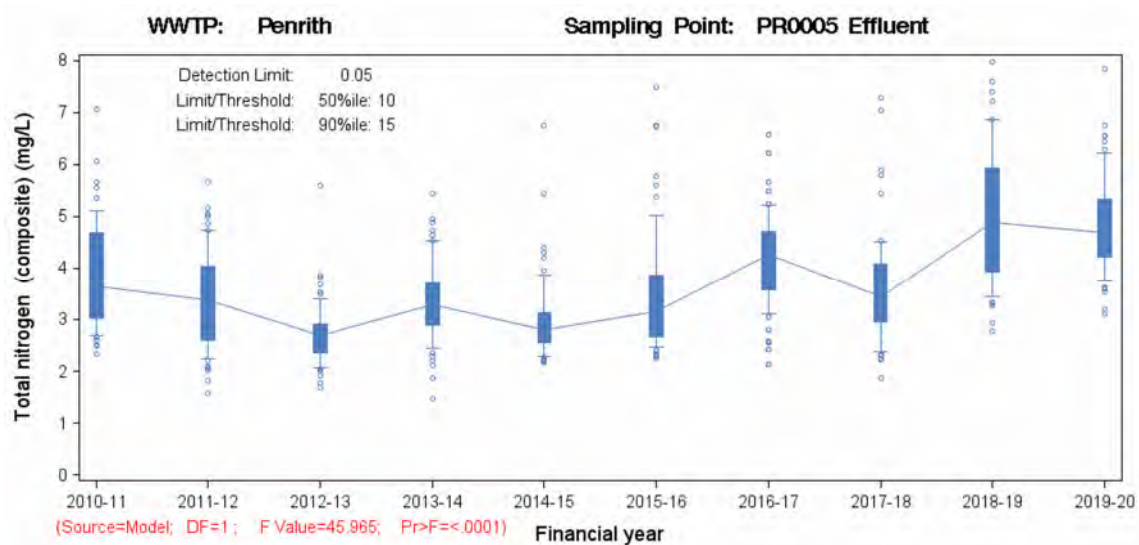
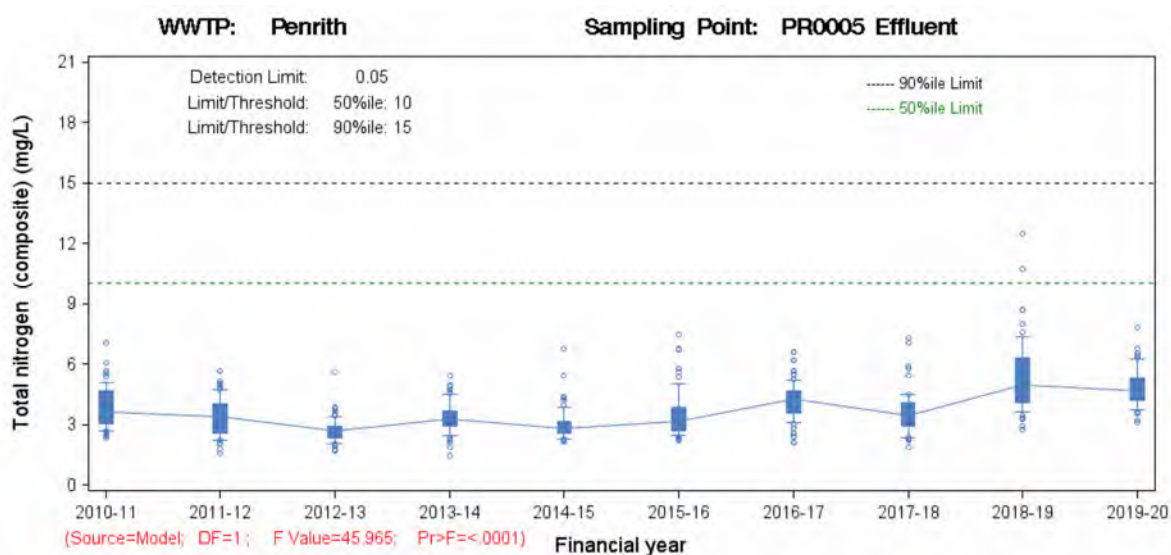
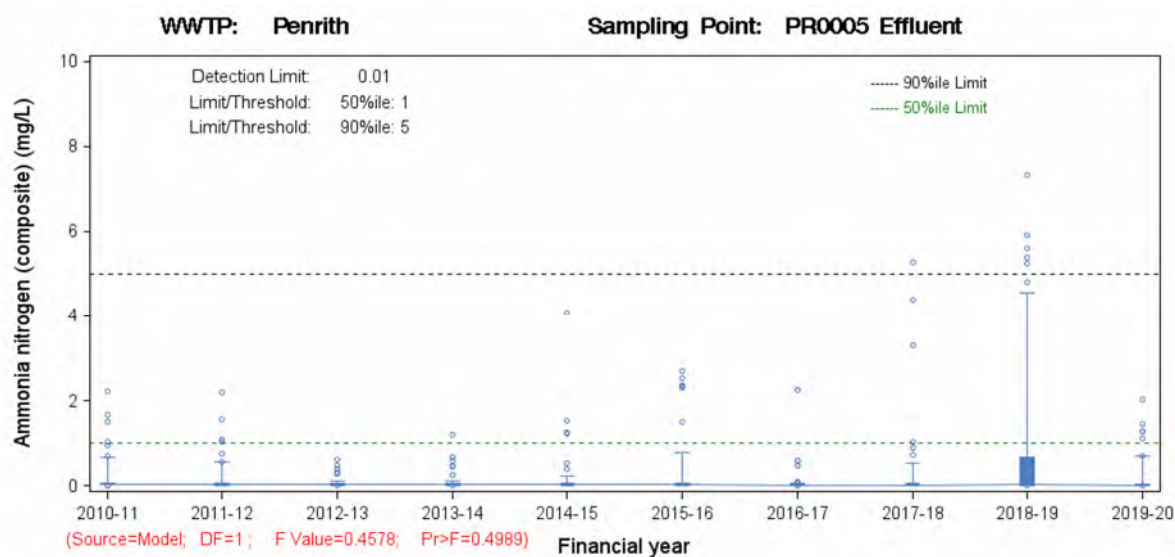


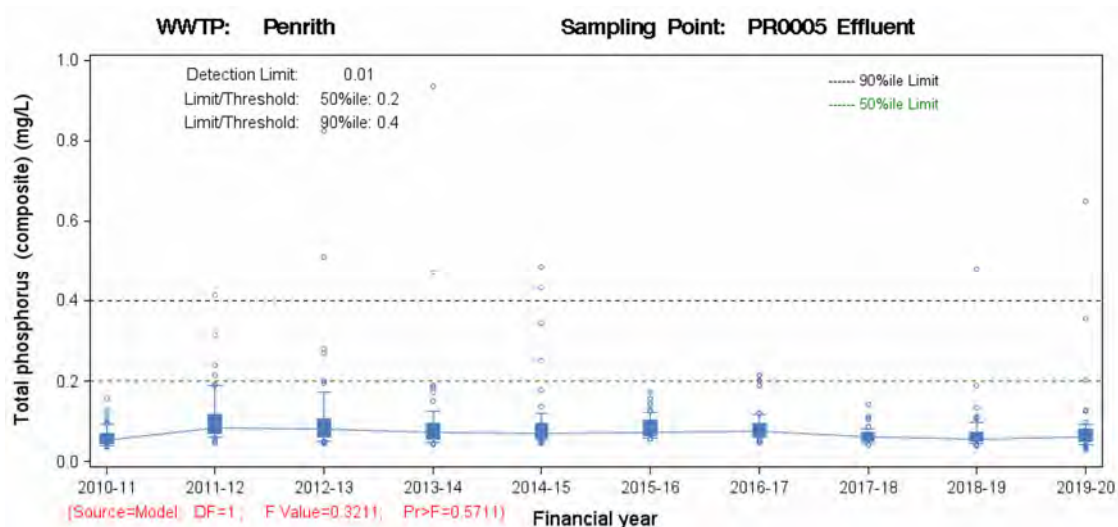


Penrith WWTP

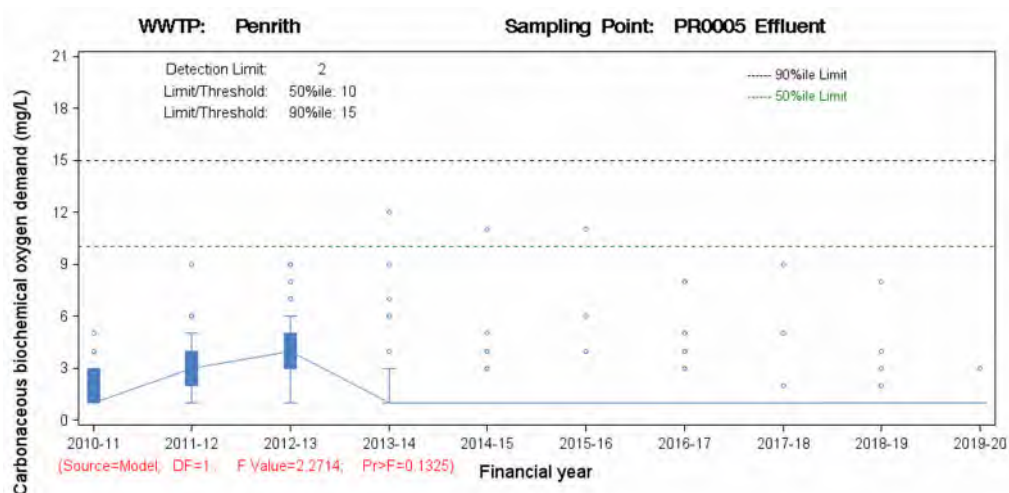
Discharge volume and rainfall



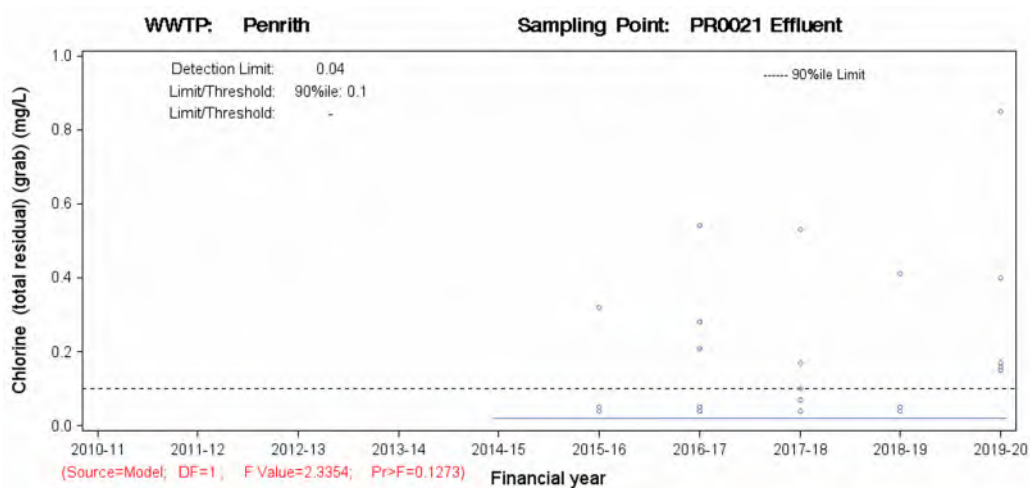




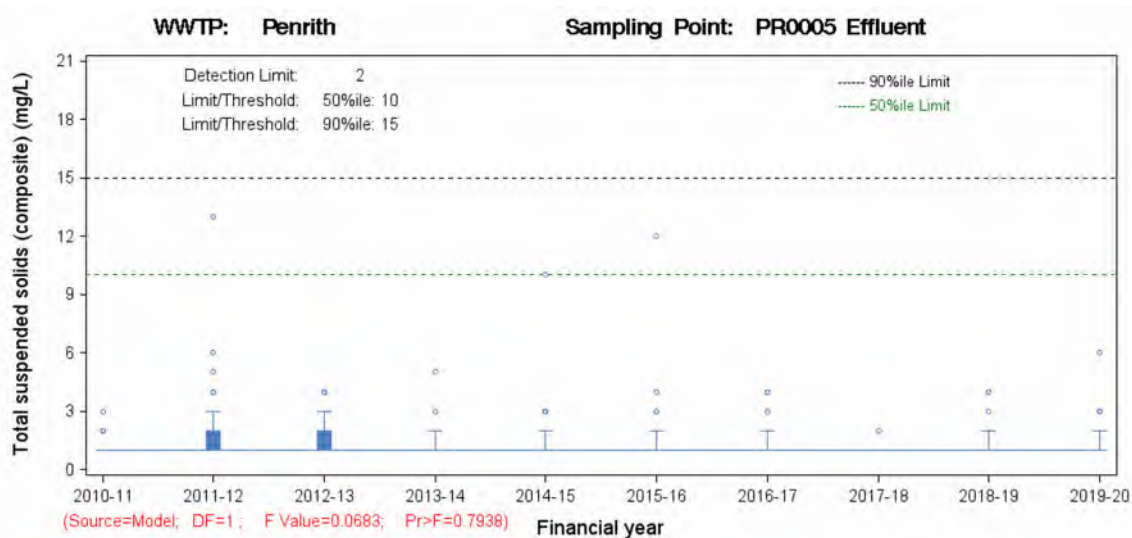
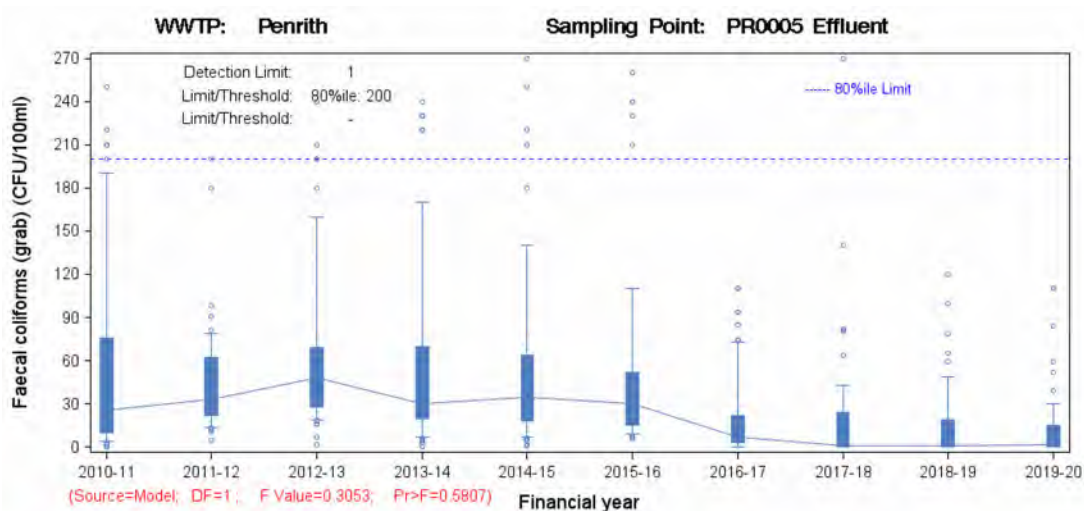
Discharge quality: Major conventional analytes



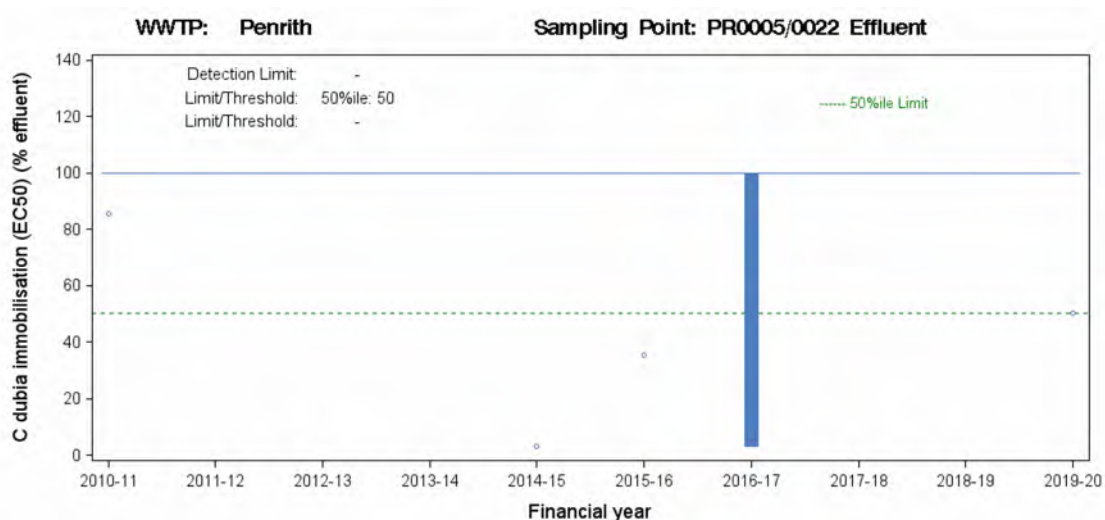
Note: Statistical test was based on 2019-20 data with previous five years data (2014-2019) due to lab method change in 2014-15.



Note: Monitoring of total chlorine residual started in January 2015.

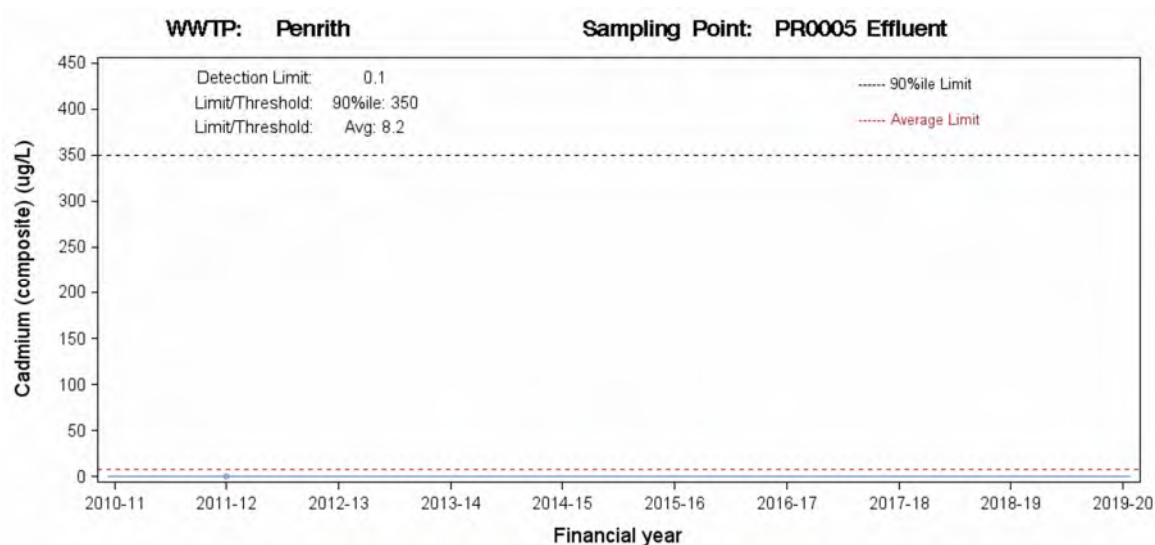
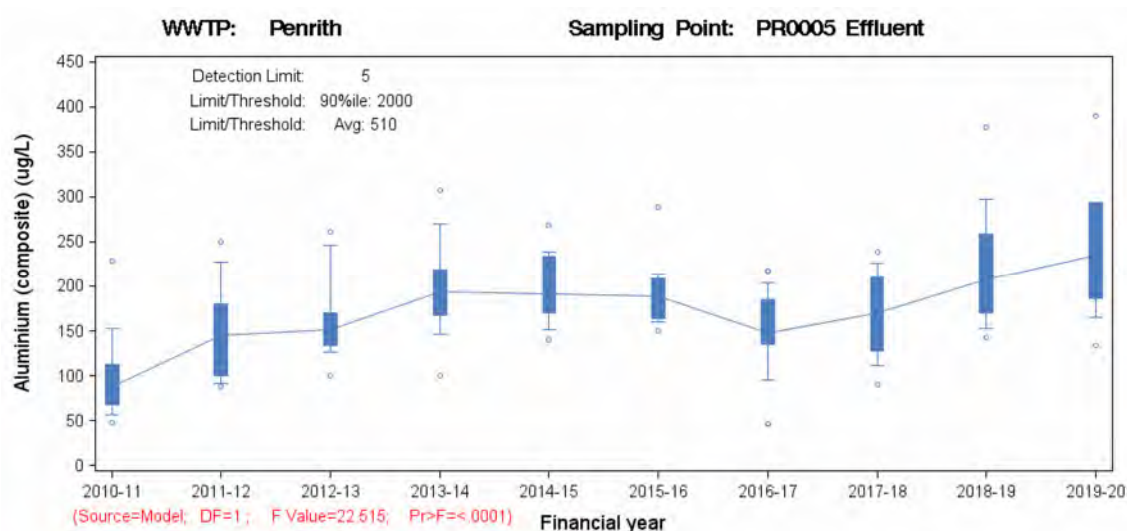
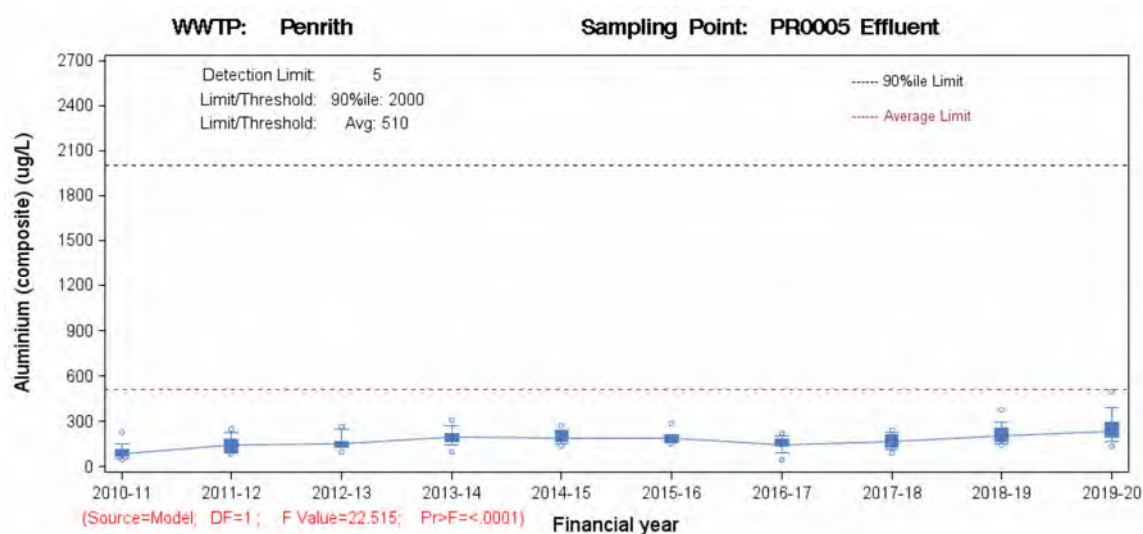


Discharge quality: Toxicity

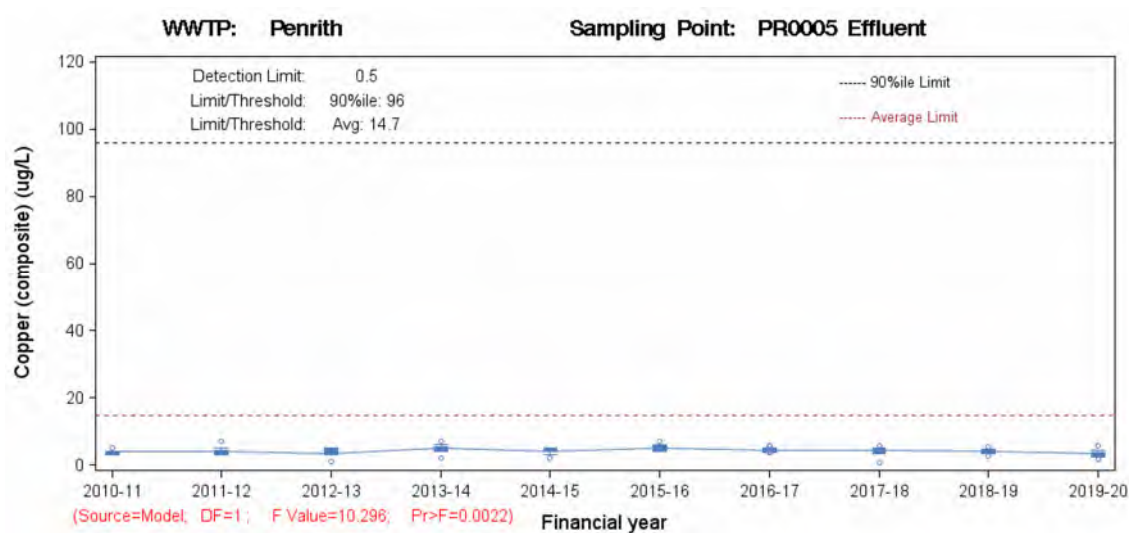
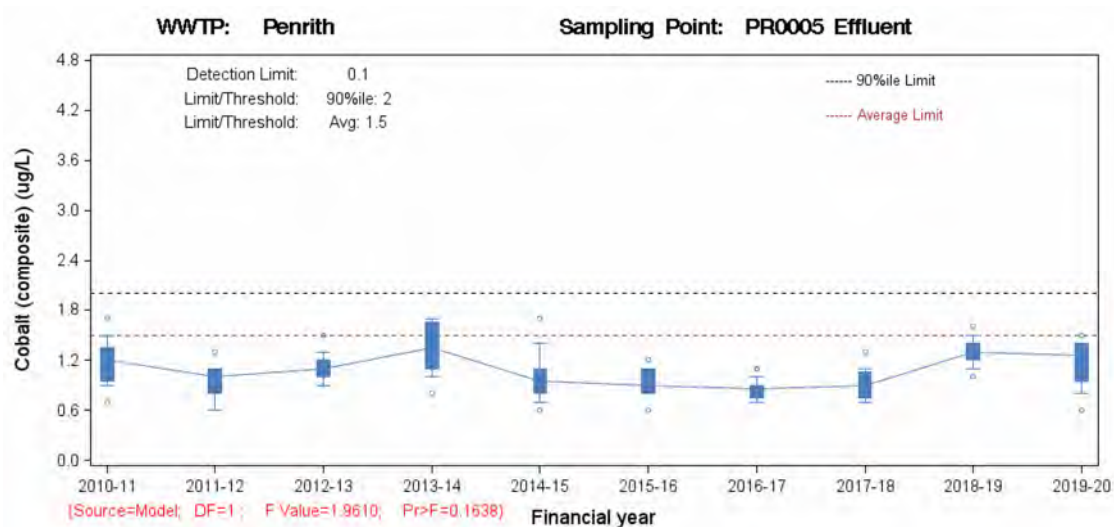


Note: Statistical test was not conducted because >90% of results were recorded at 100% survival for *Ceriodaphnia dubia*.

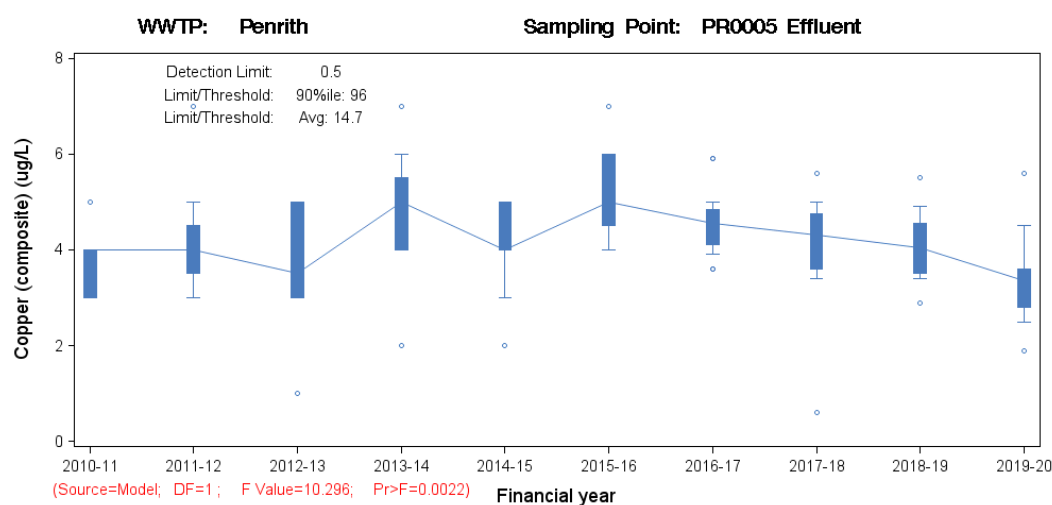
Discharge quality: Trace metals



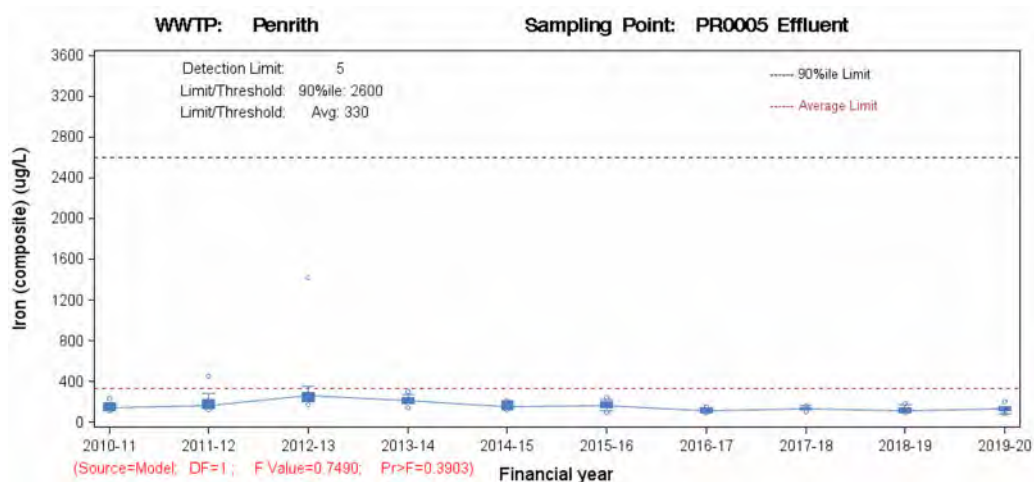
Note: 2019-20 data was compared with previous three years data (2016-2019) due to lab method change in 2016-17. Statistical test was not conducted because >90% of results were below the detection limit.



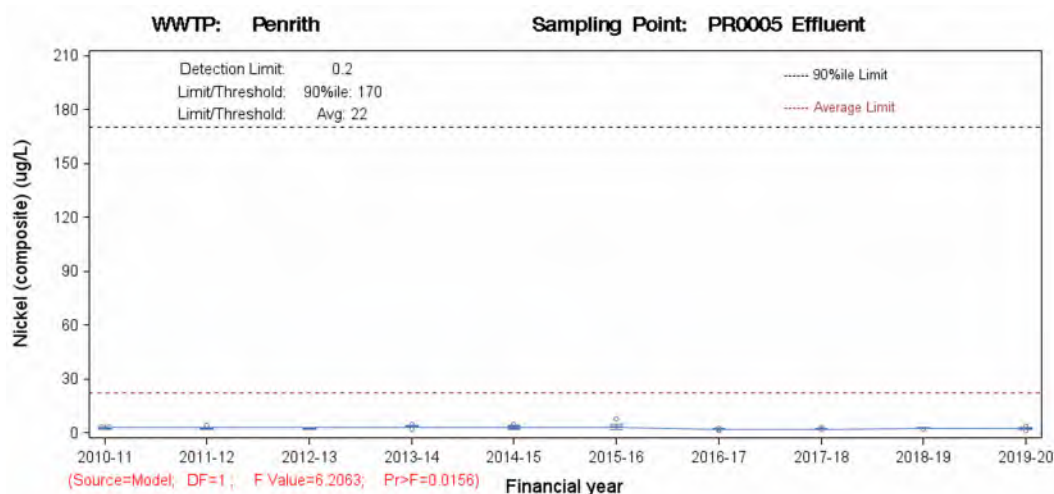
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.



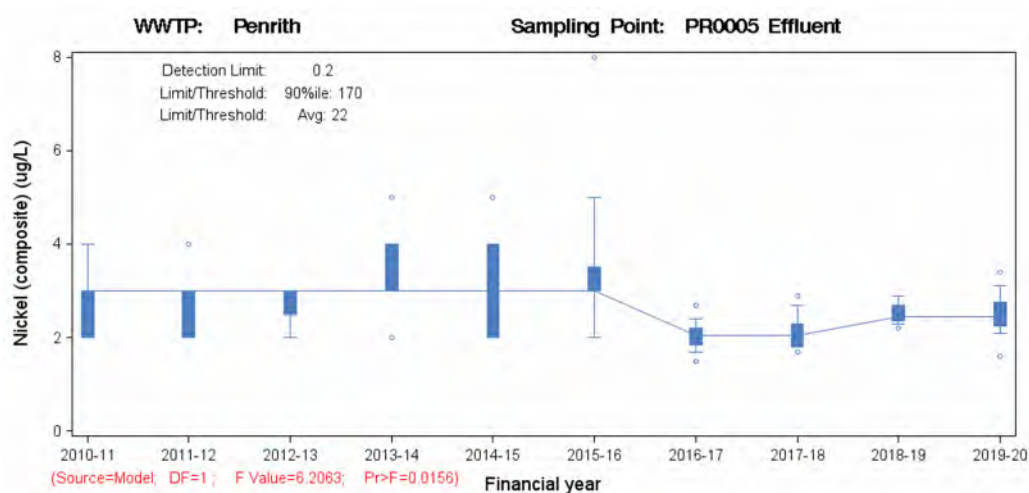
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.



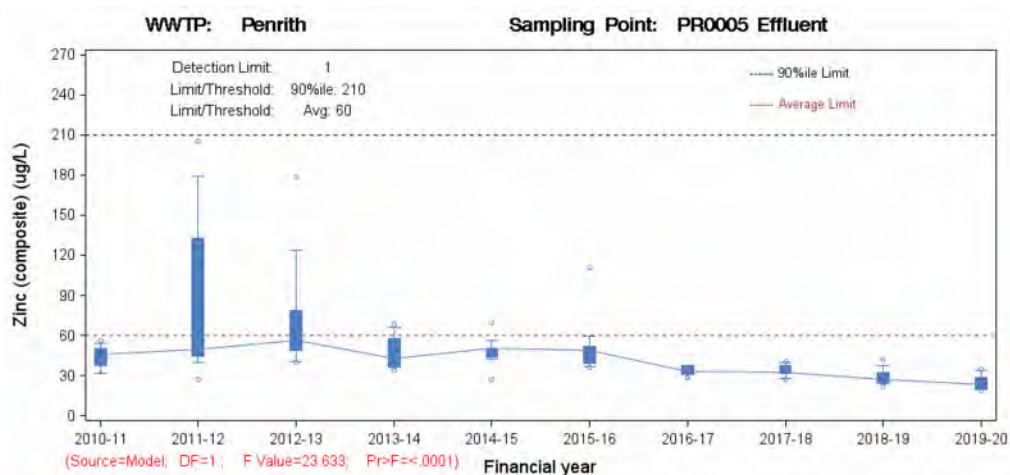
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.



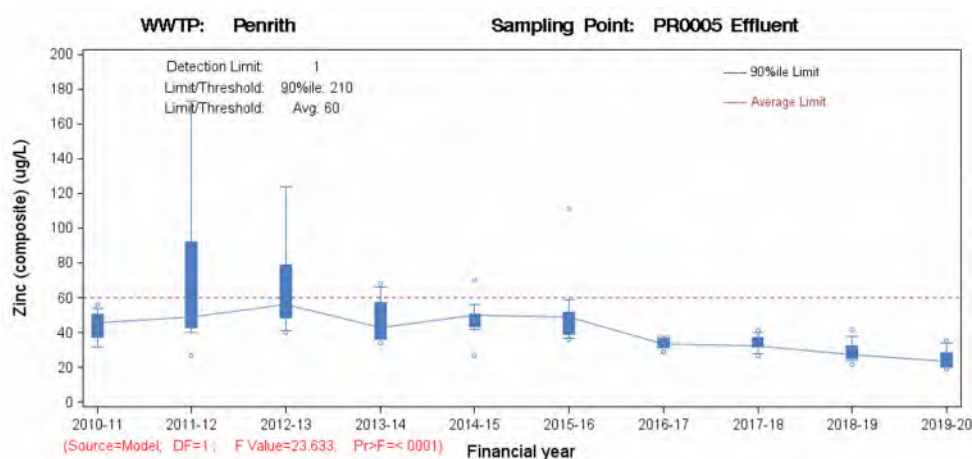
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.



Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

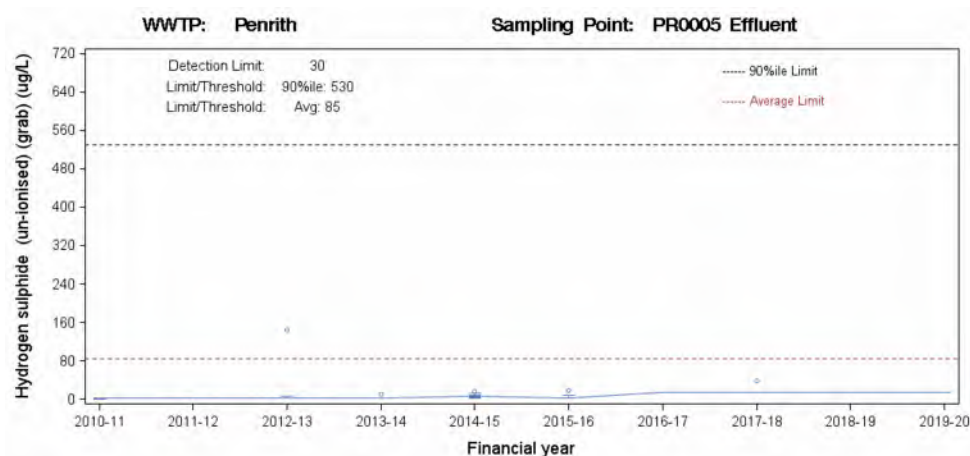


Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.



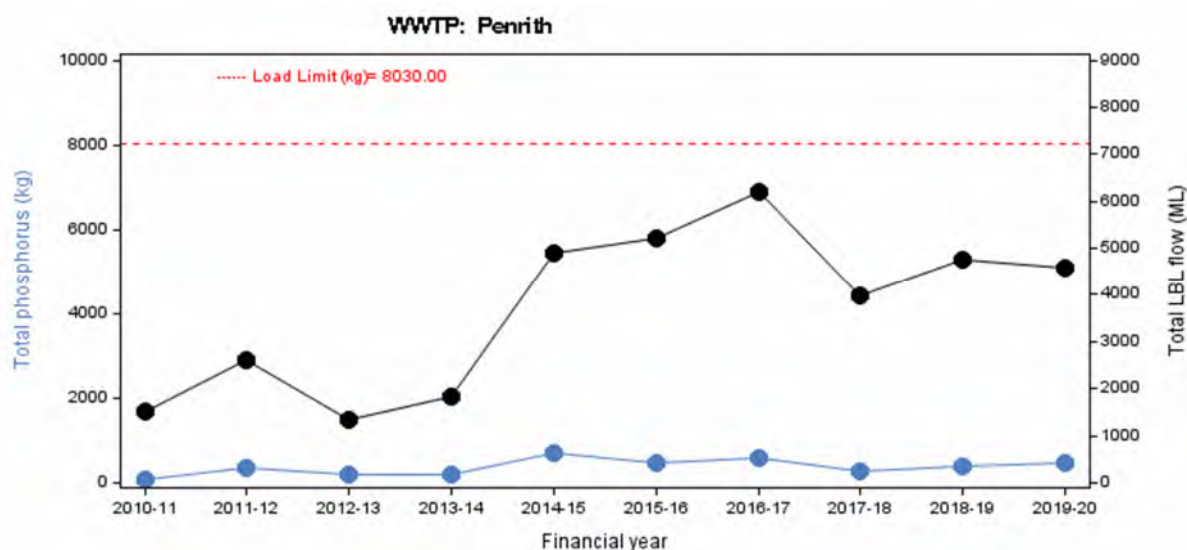
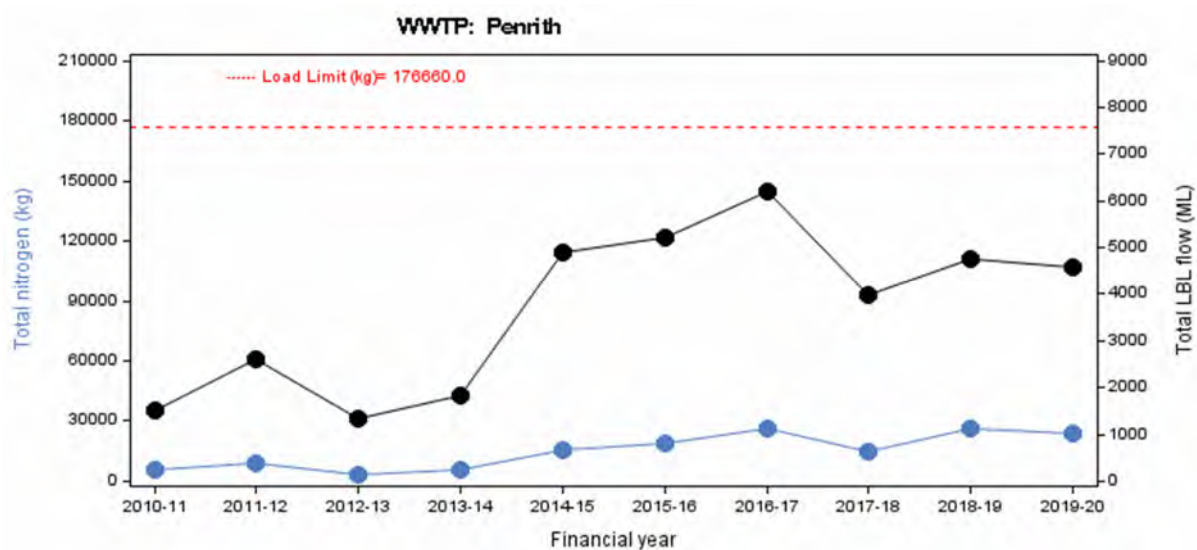
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

Discharge quality: Other chemicals and organics (including pesticides)

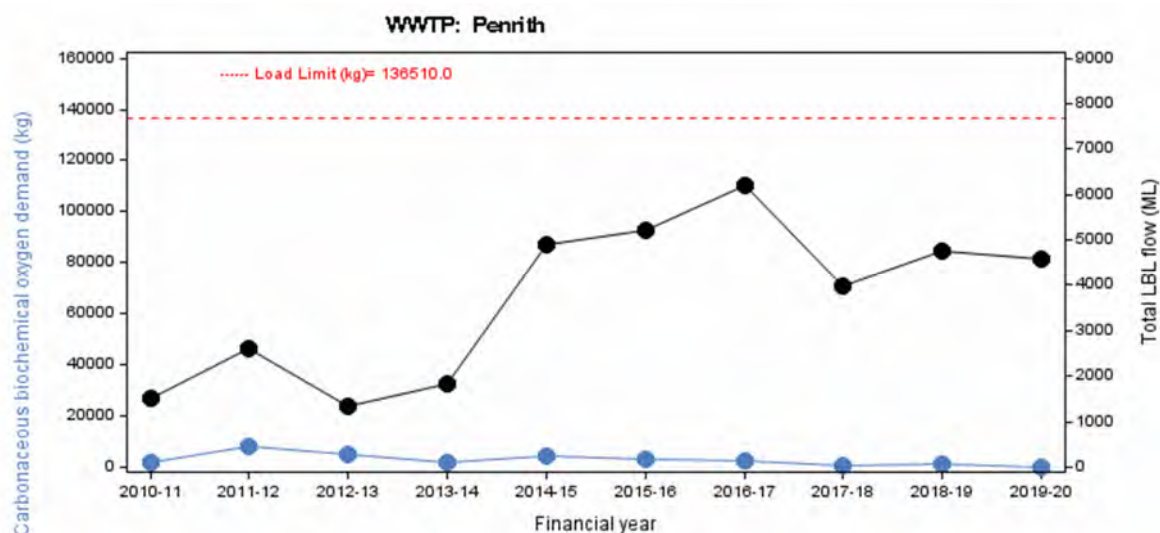


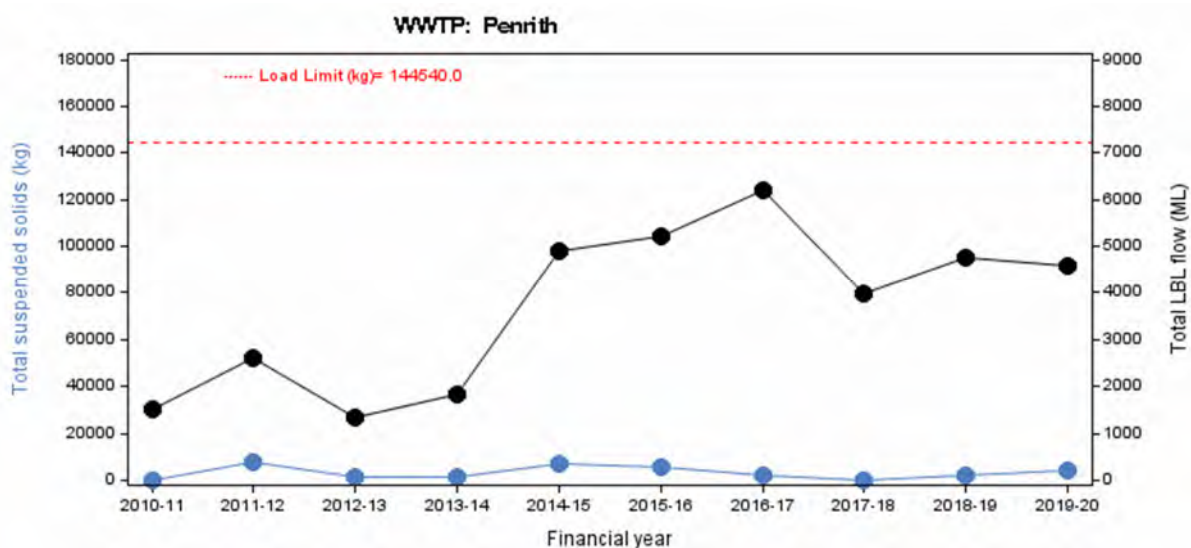
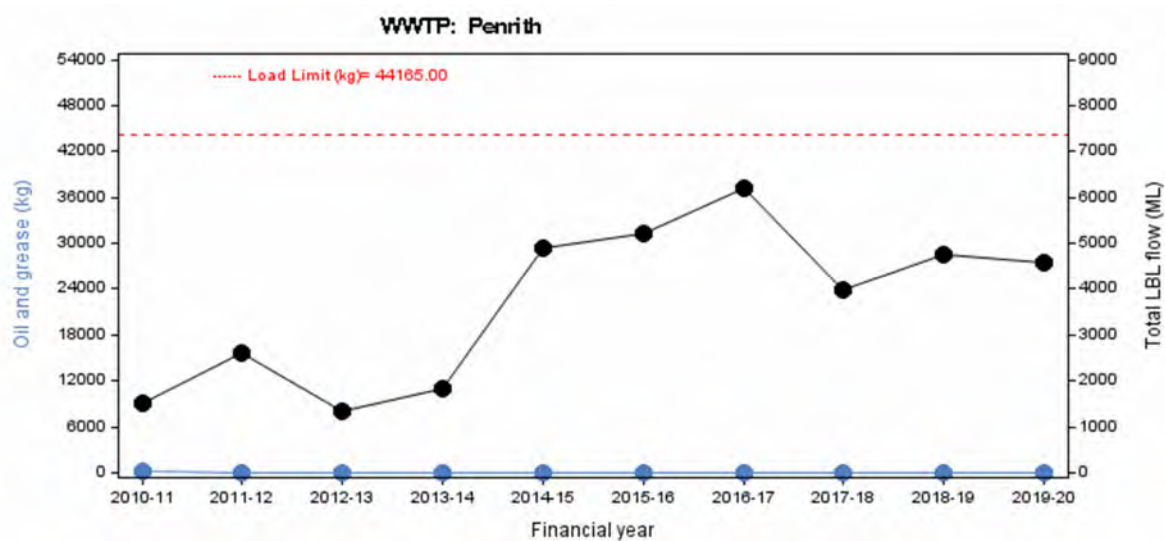
Note: 2019-20 data was compared with previous three years data (2016-2019) due to lab method change in 2016-17. Statistical test was not conducted because >90% of results were below the detection limit.

Discharge load: Nutrients

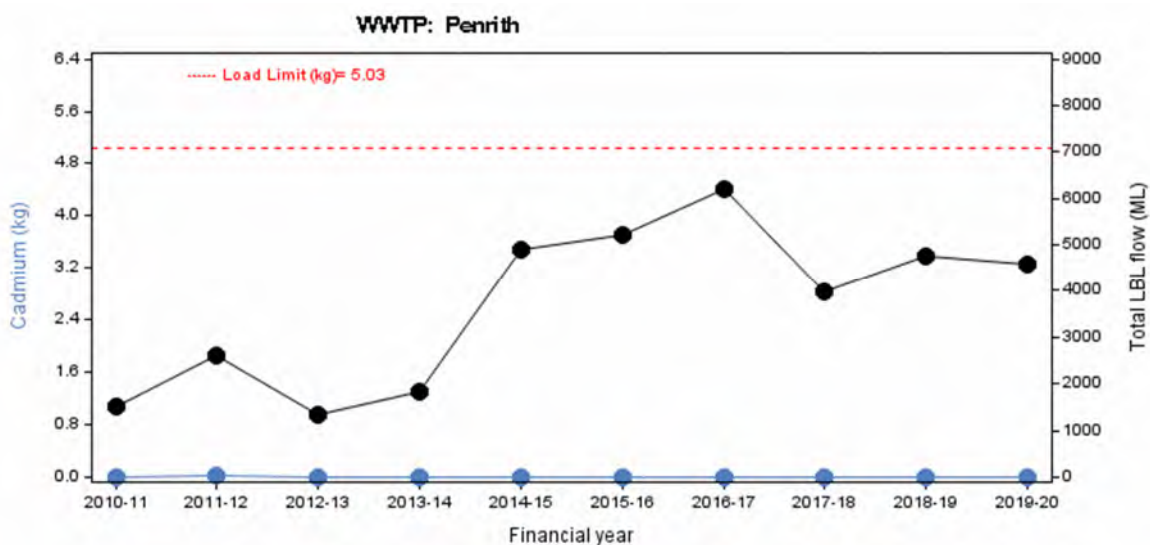


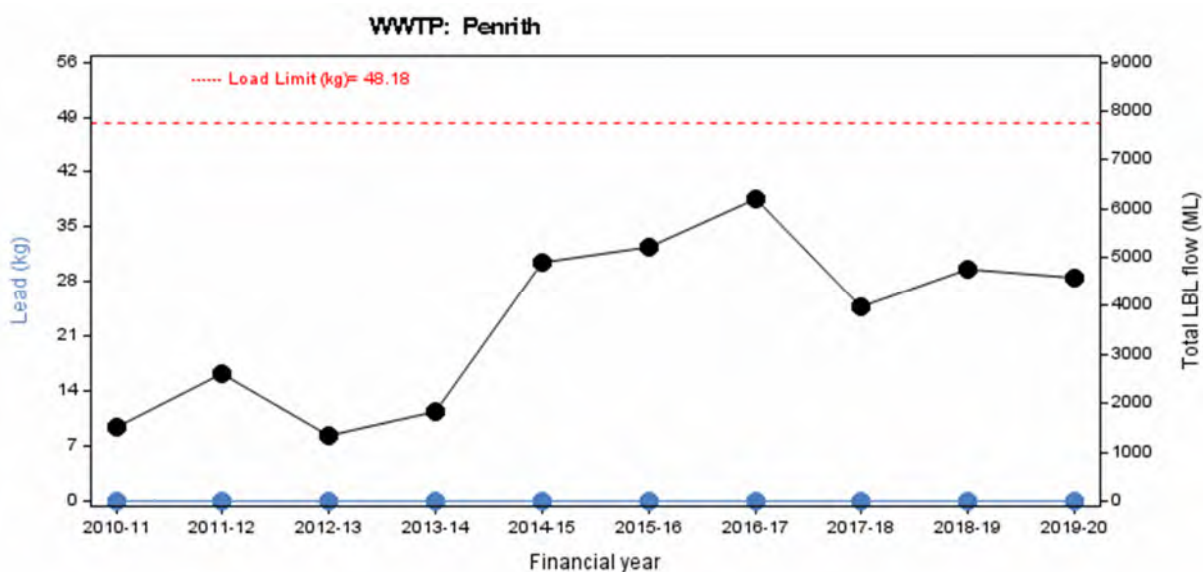
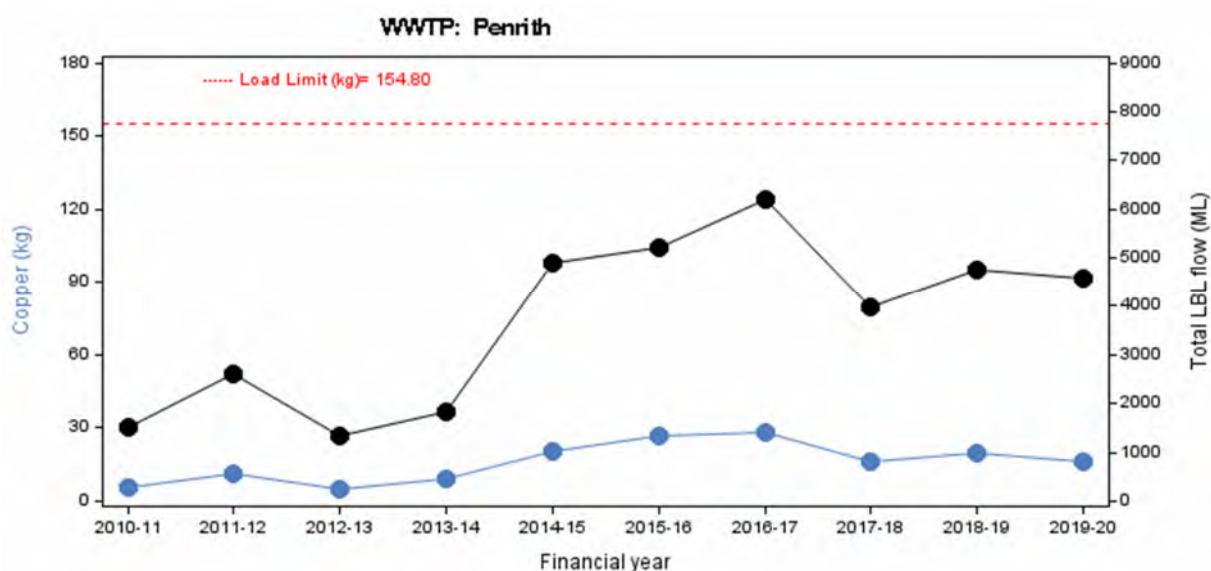
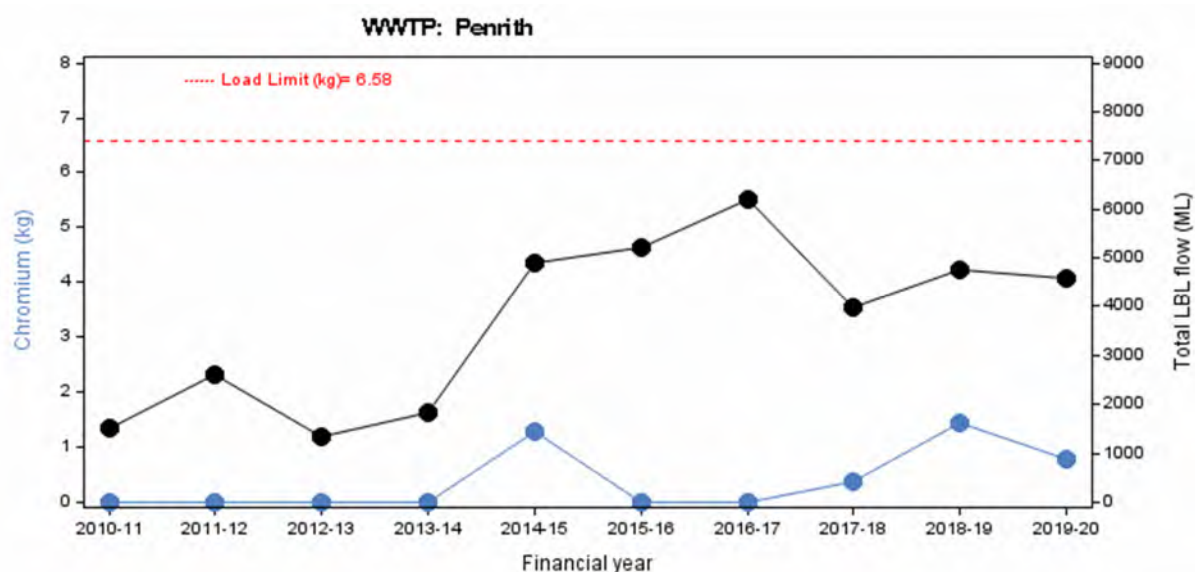
Discharge load: Major conventional analytes

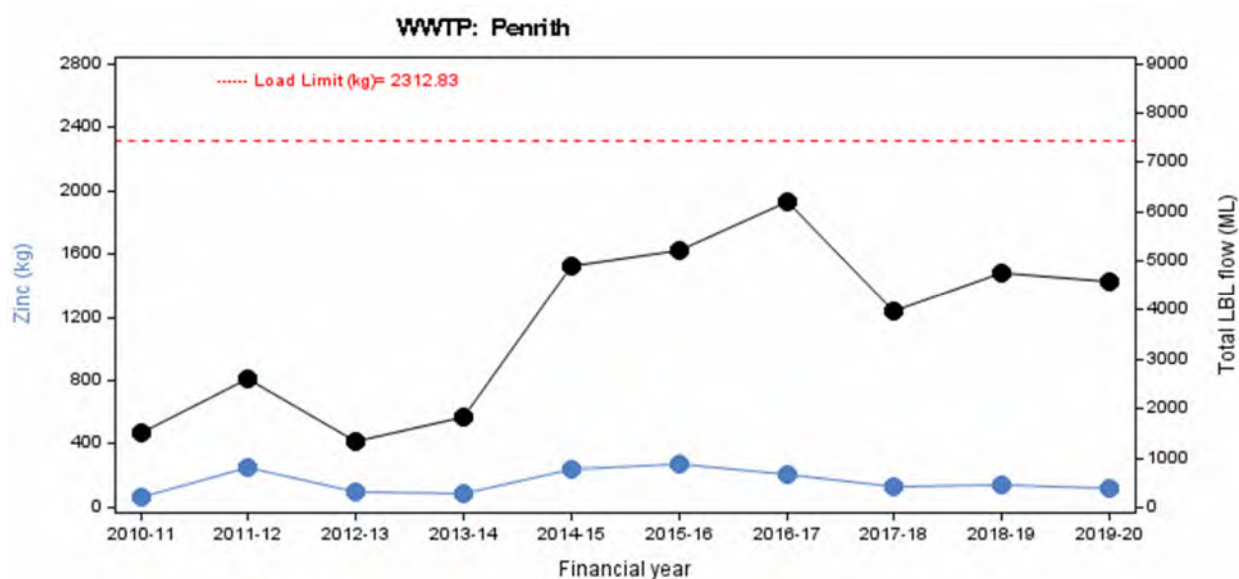
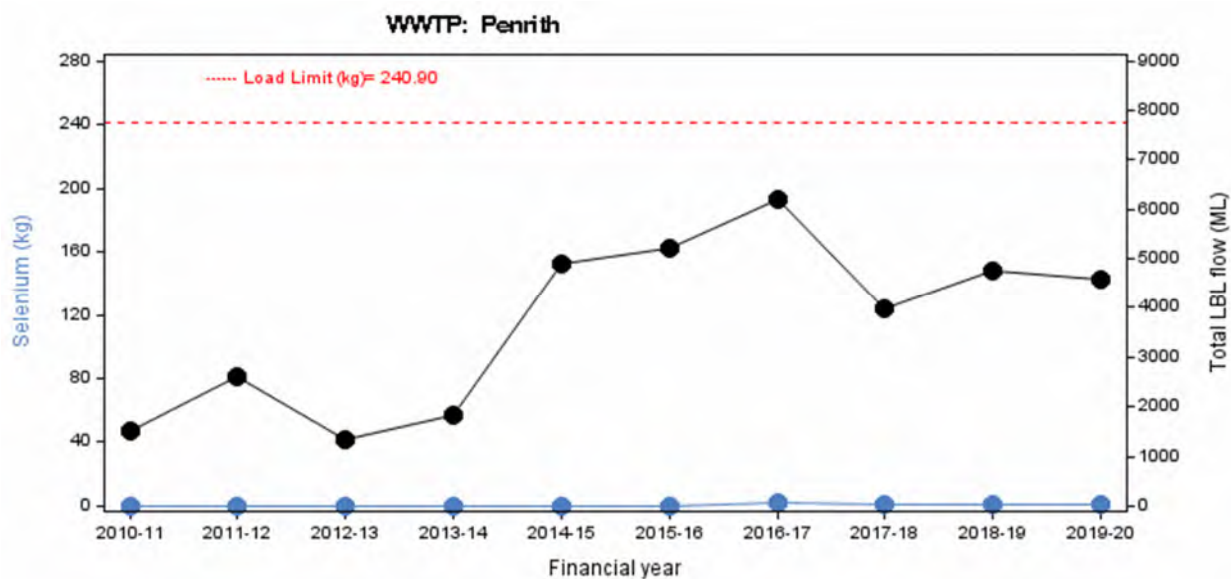
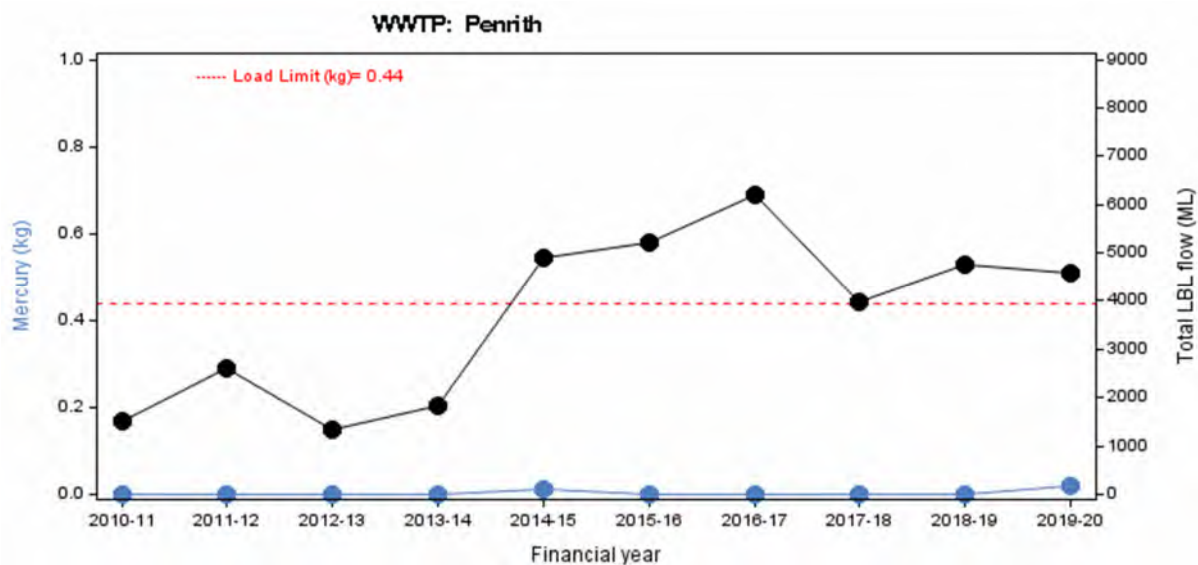




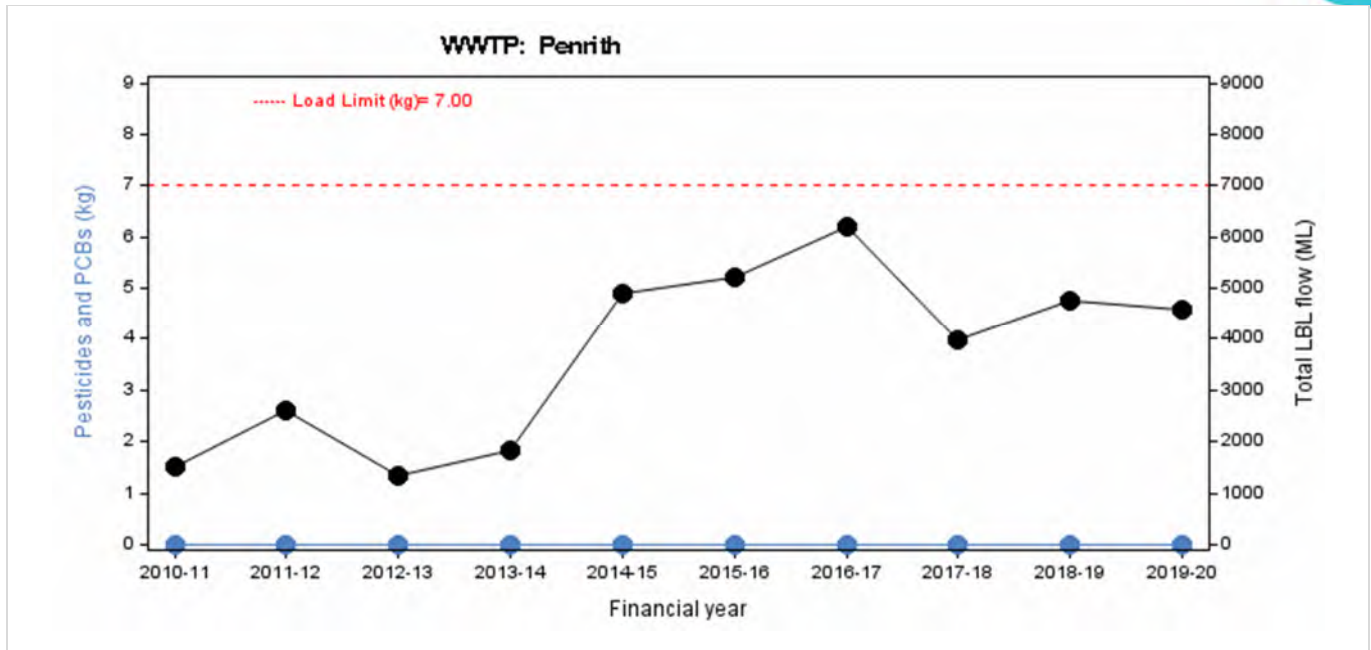
Discharge load: Trace metals





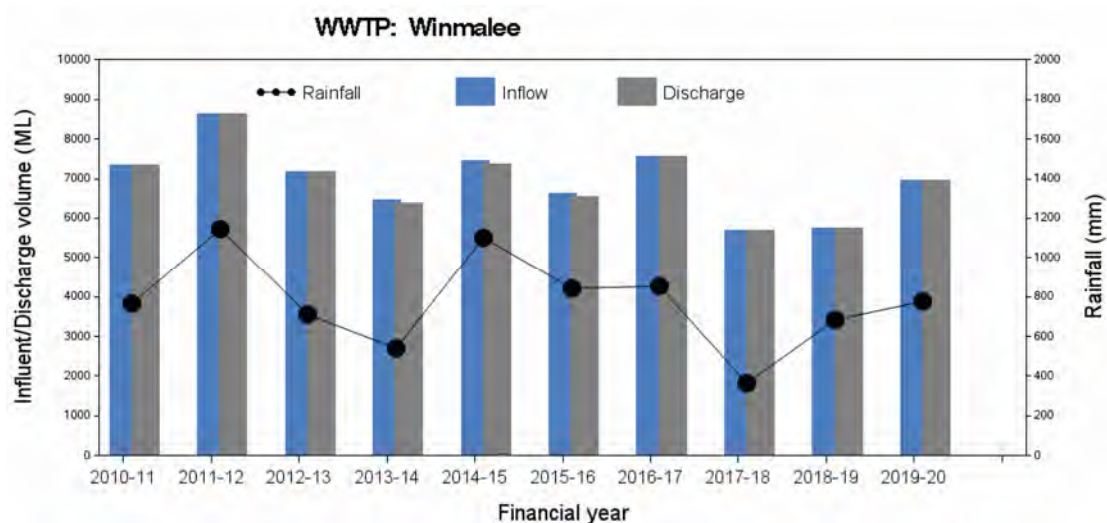


Discharge load: Other chemical and organics (including pesticides)

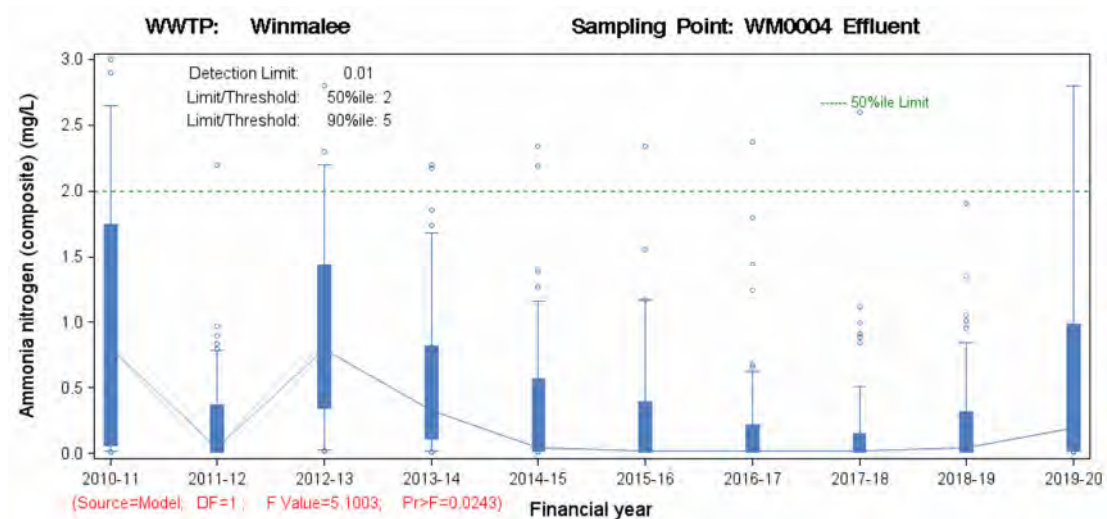
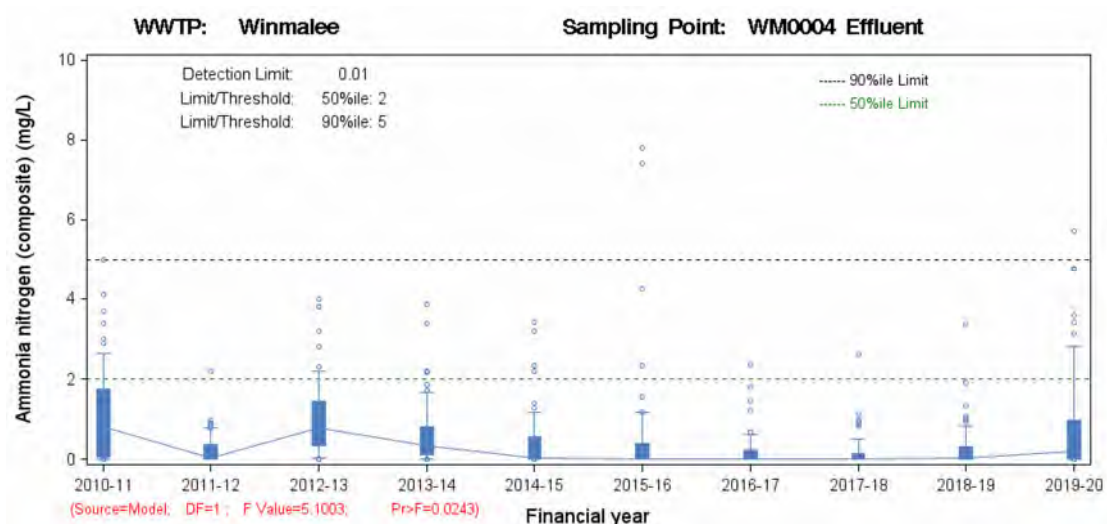


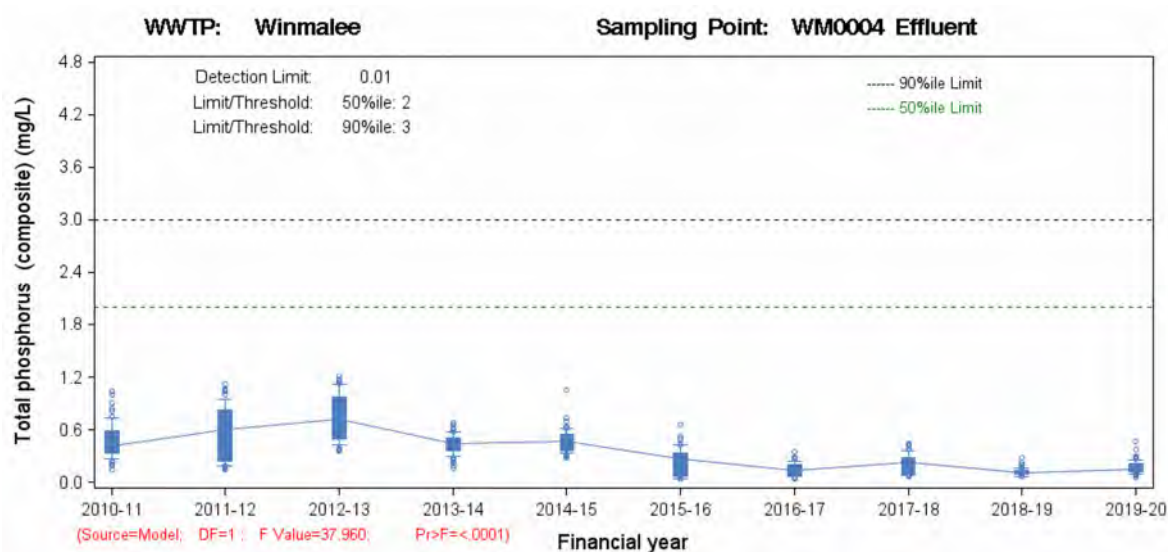
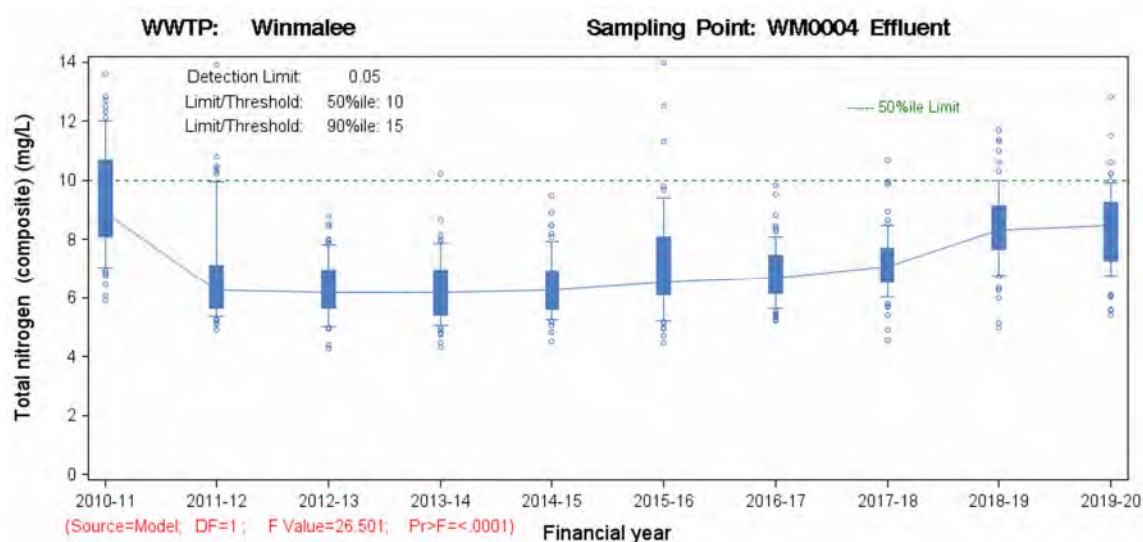
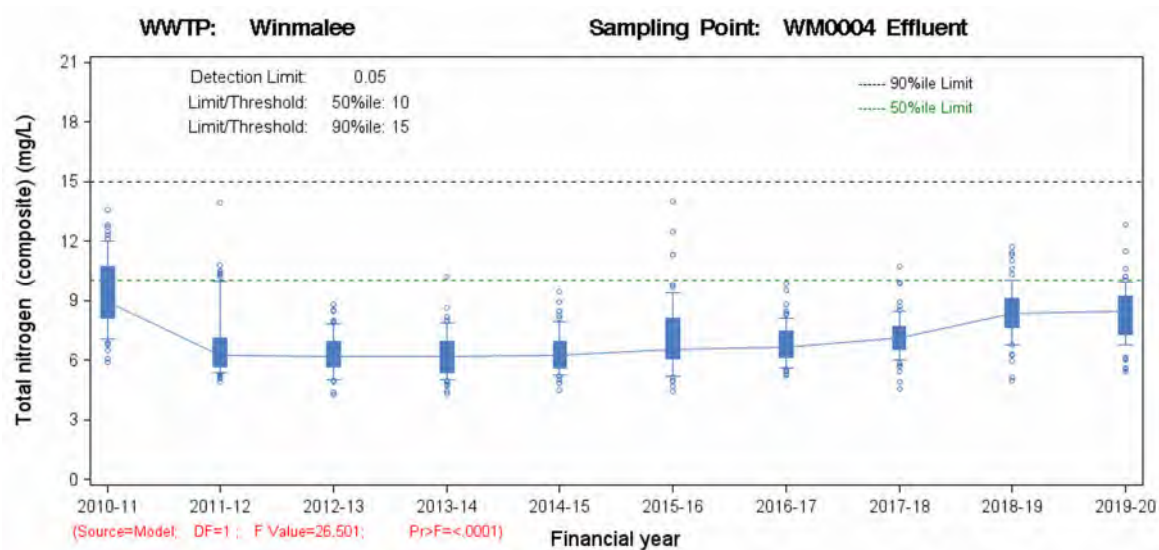
Winmalee WWTP

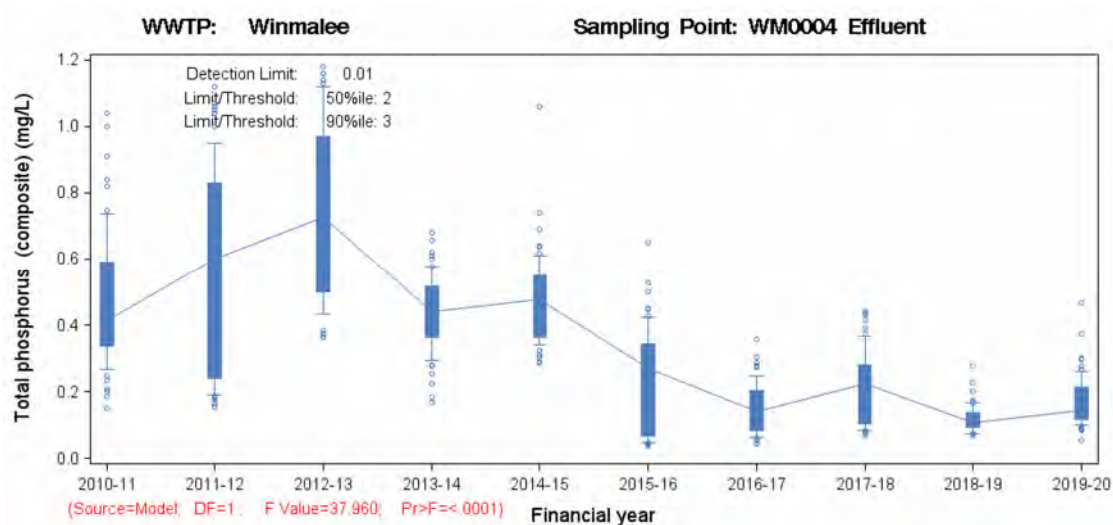
Discharge volume and rainfall



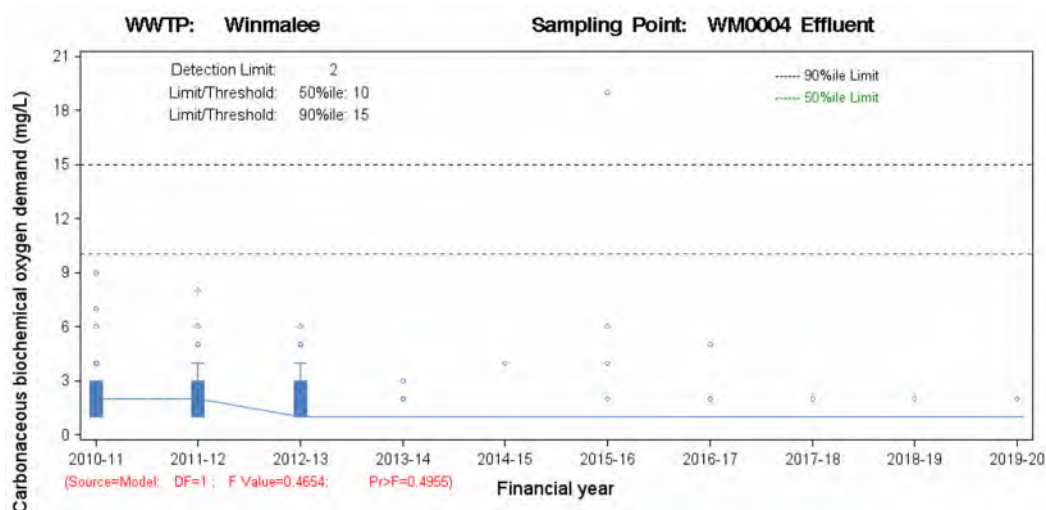
Discharge quality: Nutrients



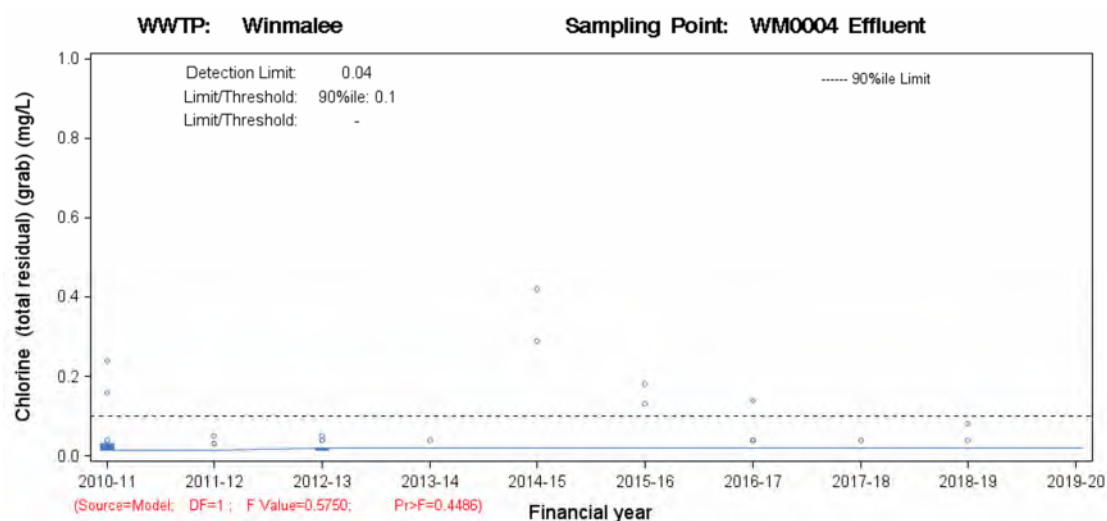


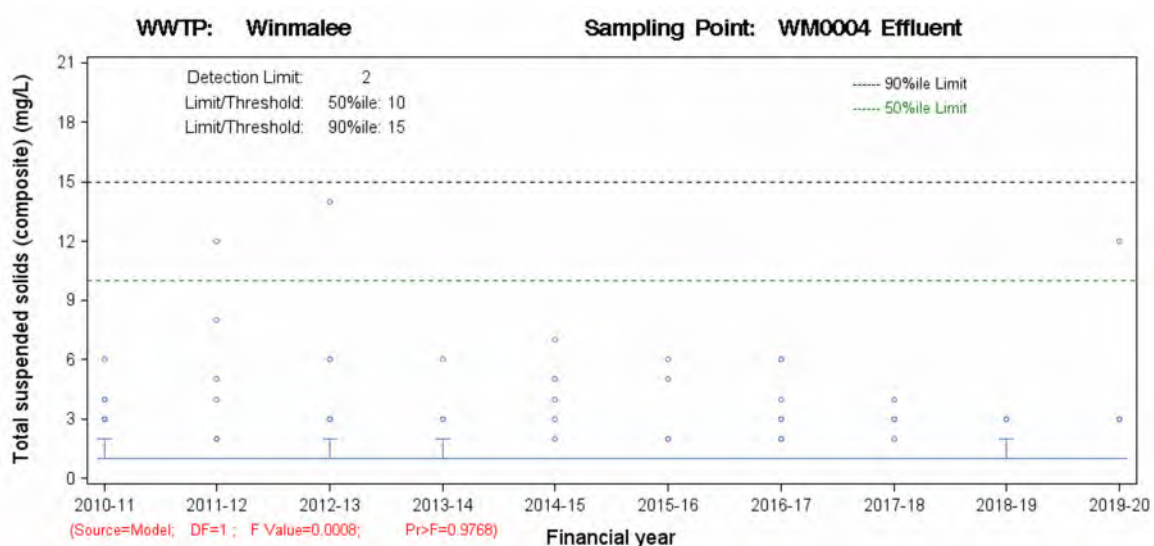
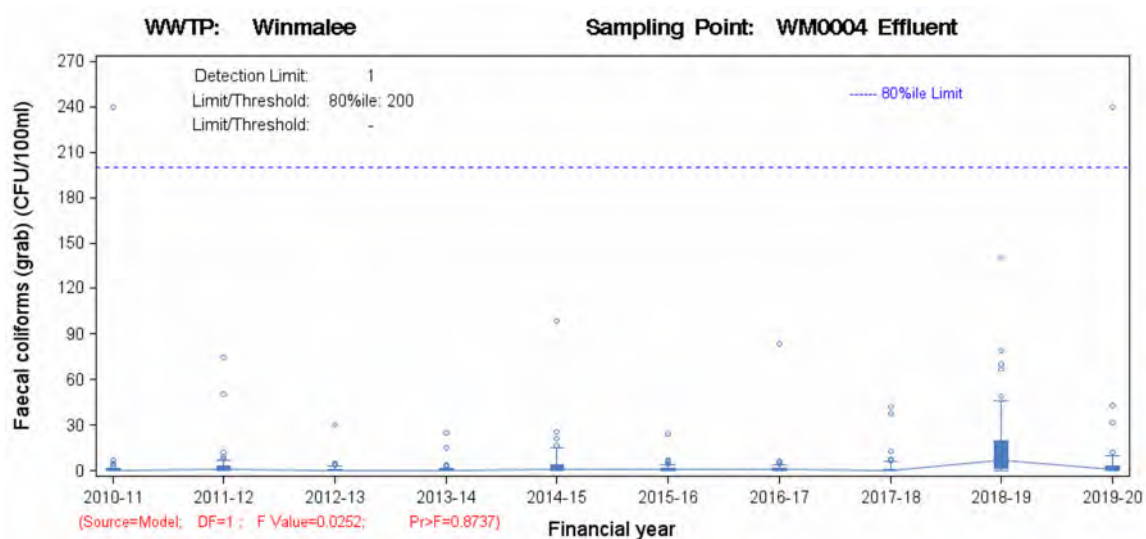


Discharge quality: Major conventional analytes

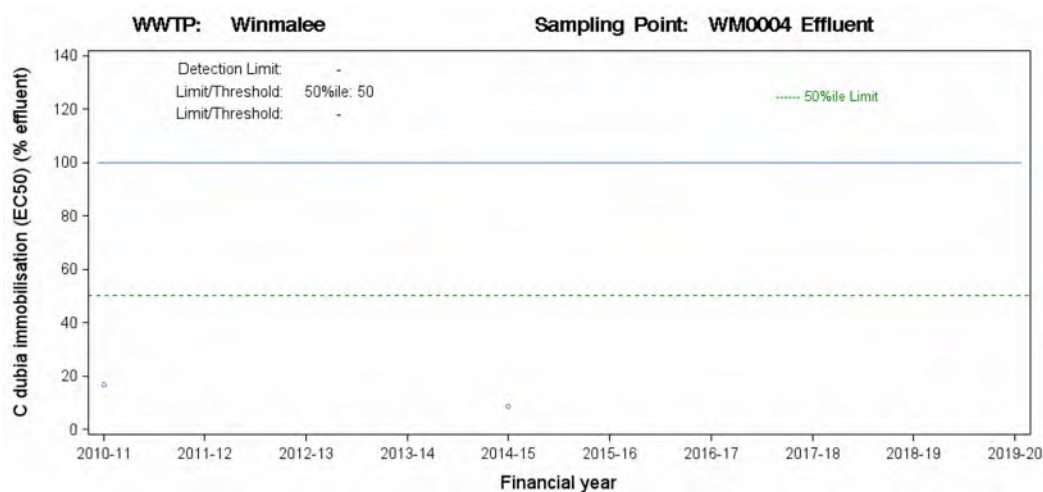


Note: Statistical test was based on 2019-20 data with previous five years data (2014-2019) due to lab method change in 2014-15.



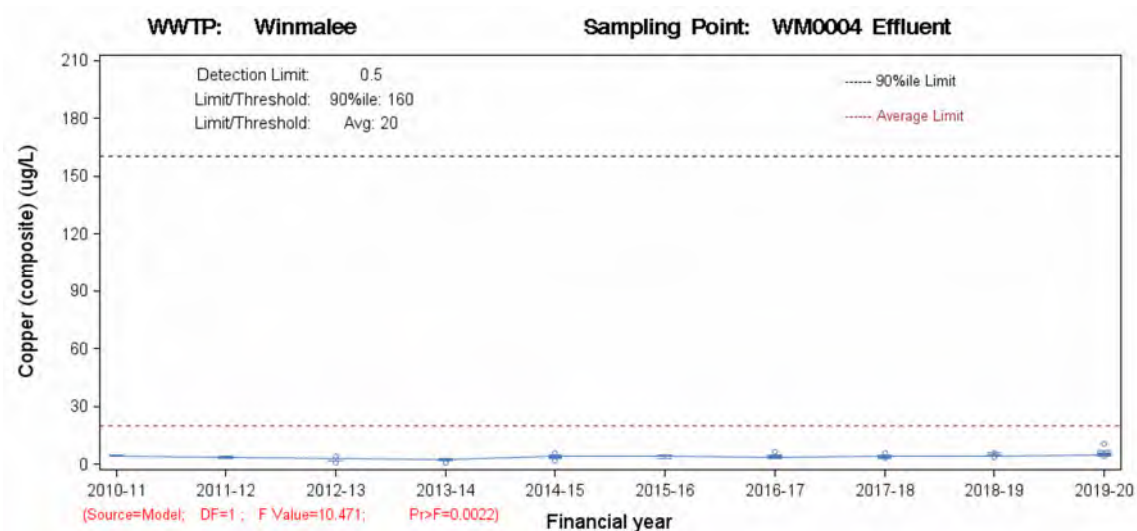
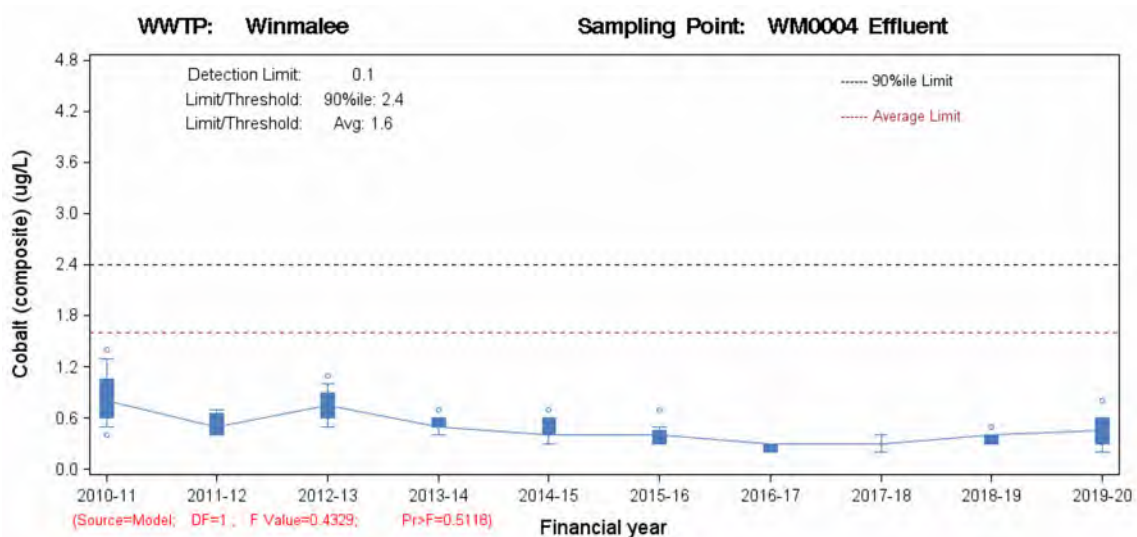
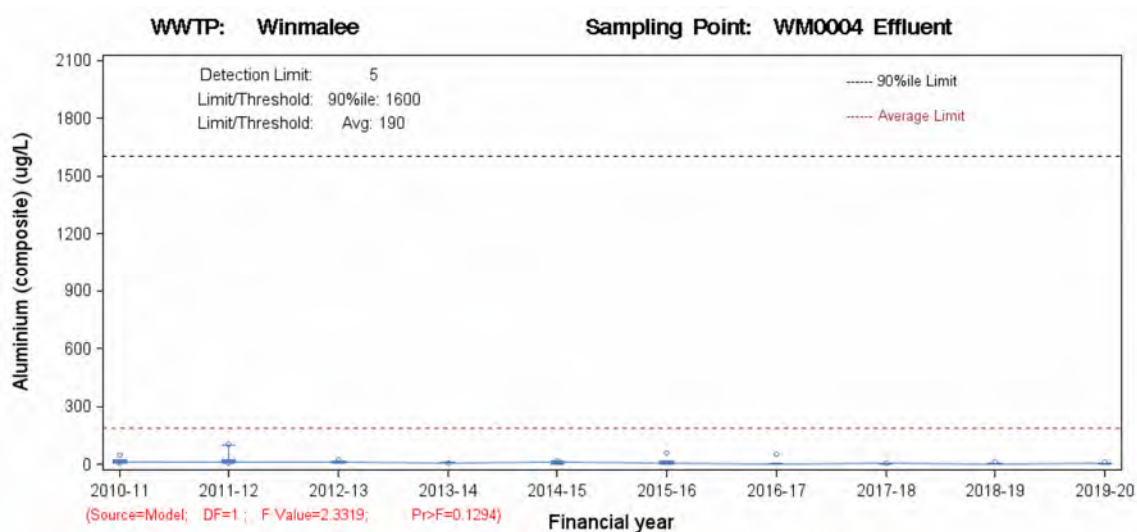


Discharge quality: Toxicity

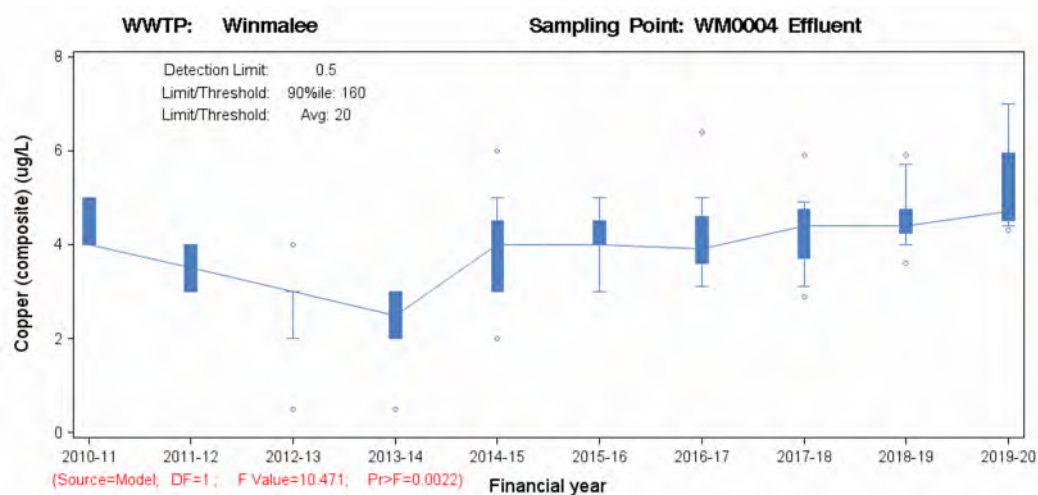


Note: Statistical test was not conducted because >90% of results were recorded at 100% survival for *Ceriodaphnia dubia*.

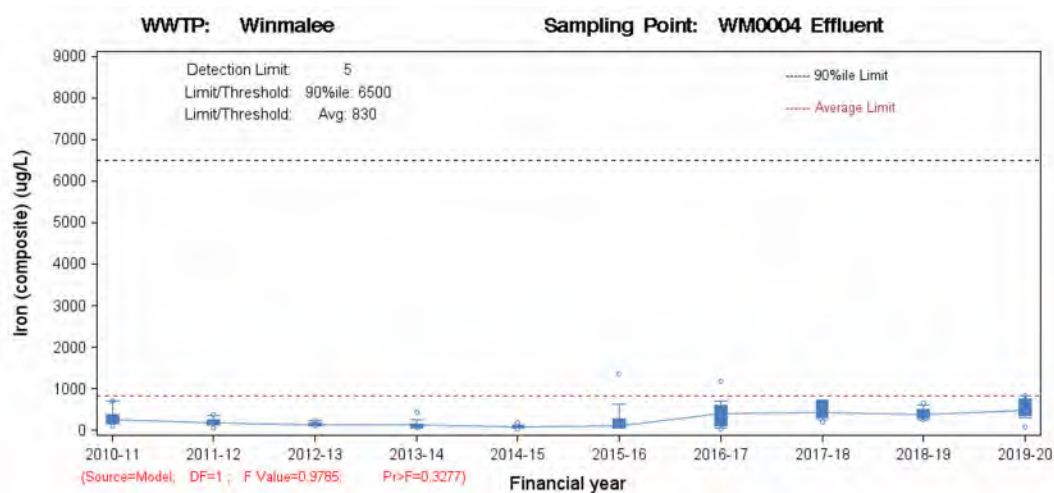
Discharge quality: Trace metals



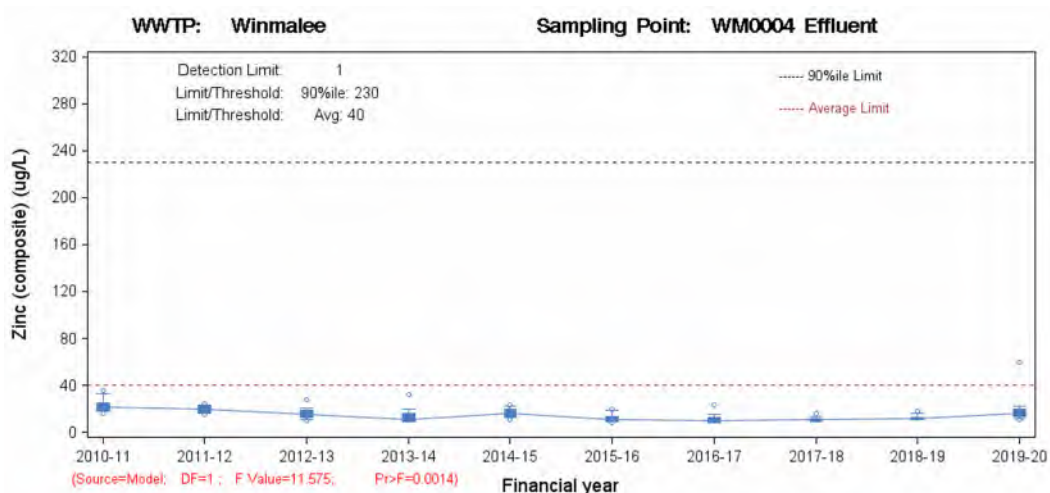
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.



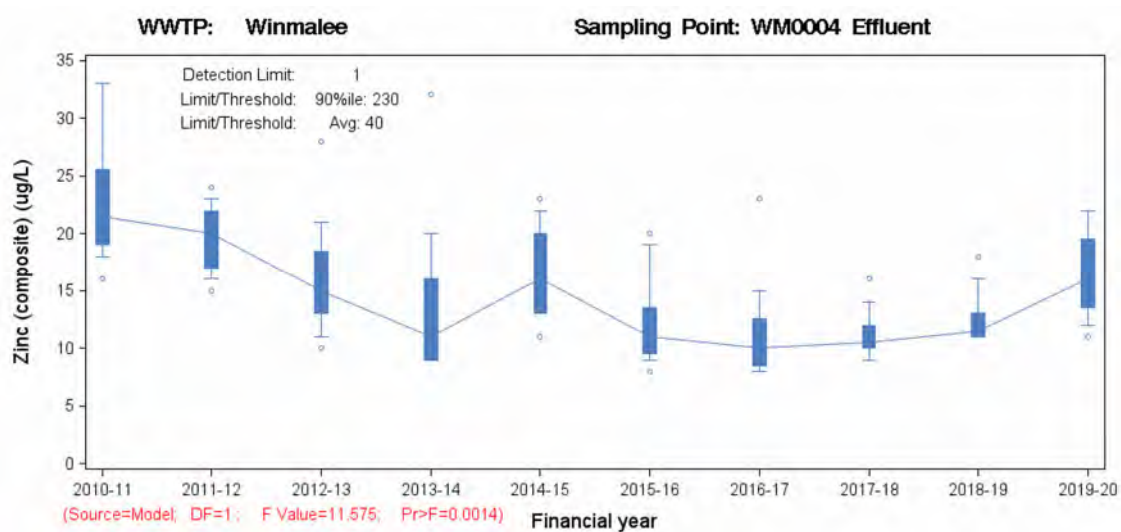
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.



Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

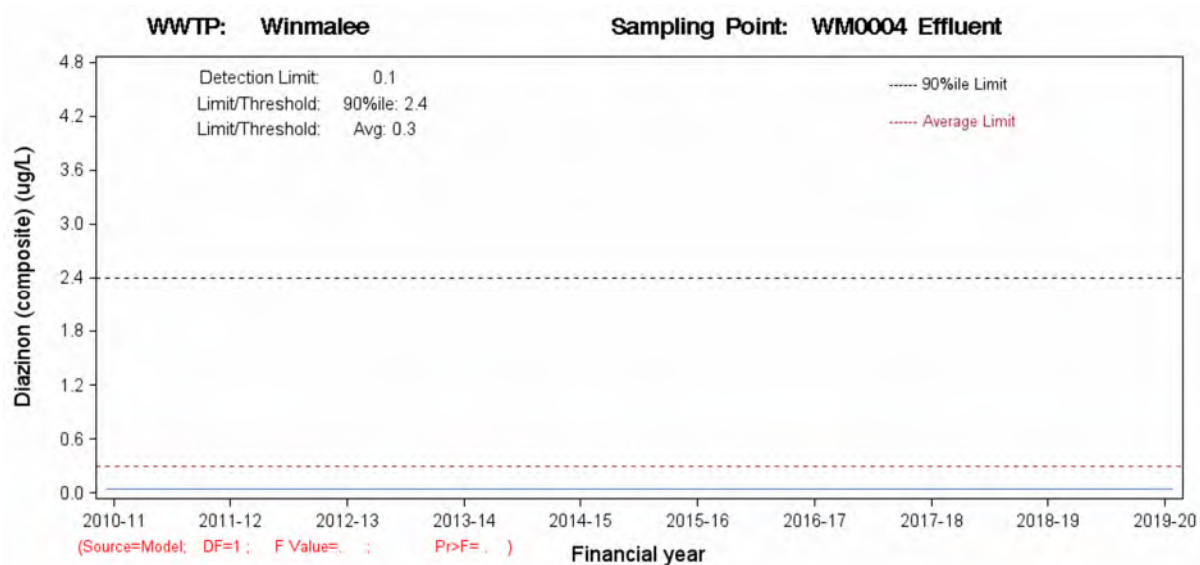


Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.



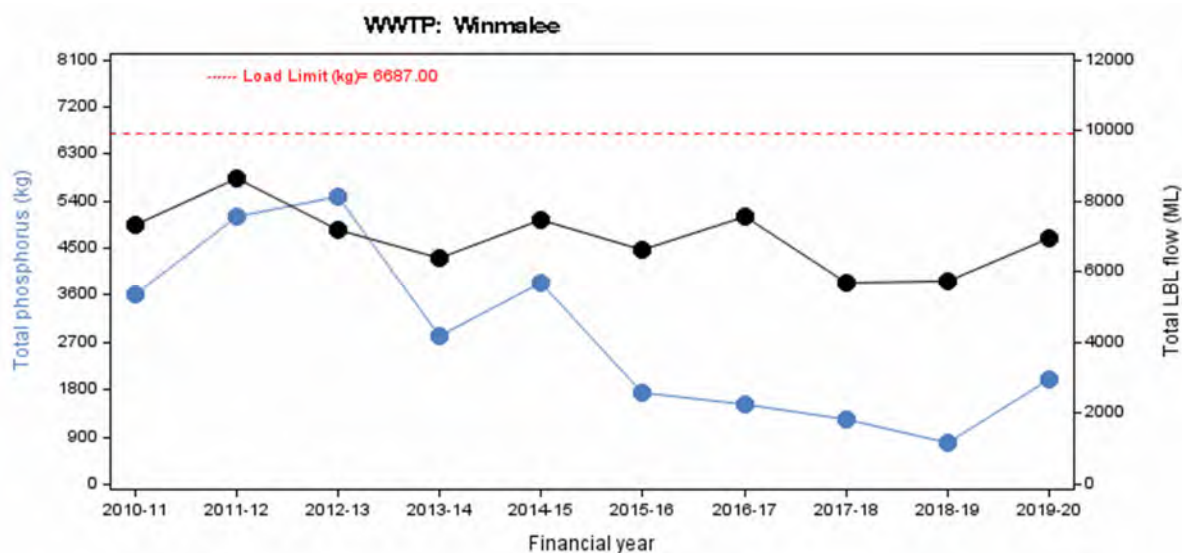
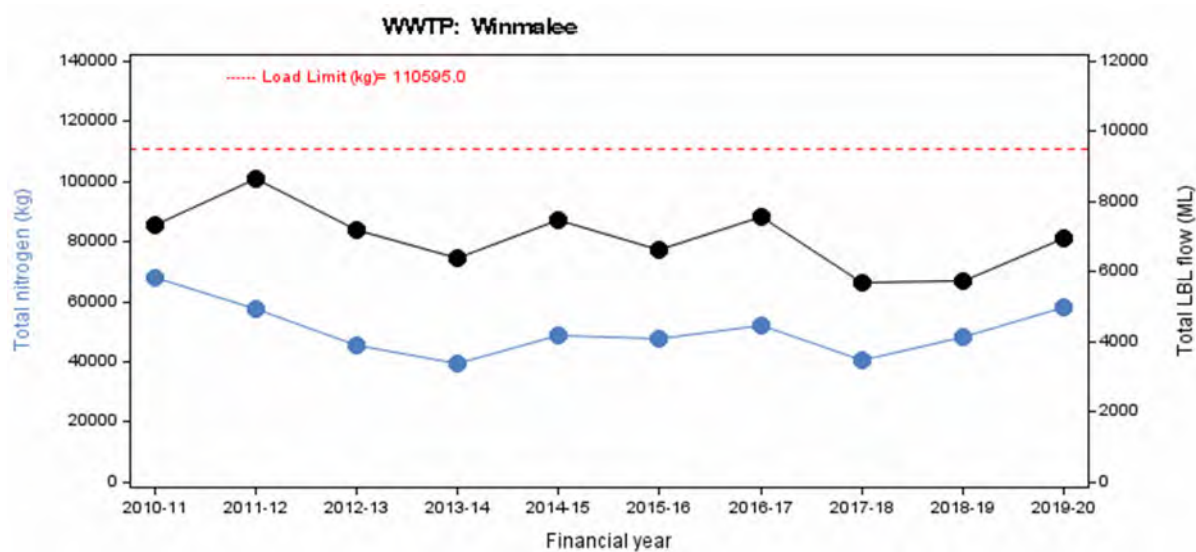
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

Discharge quality: Other chemicals and organics (including pesticides)

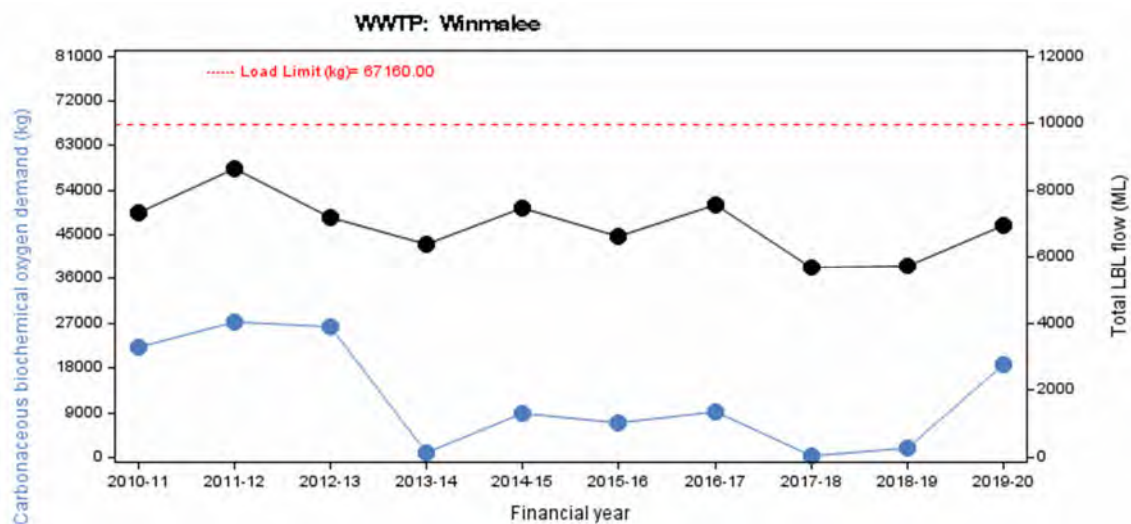


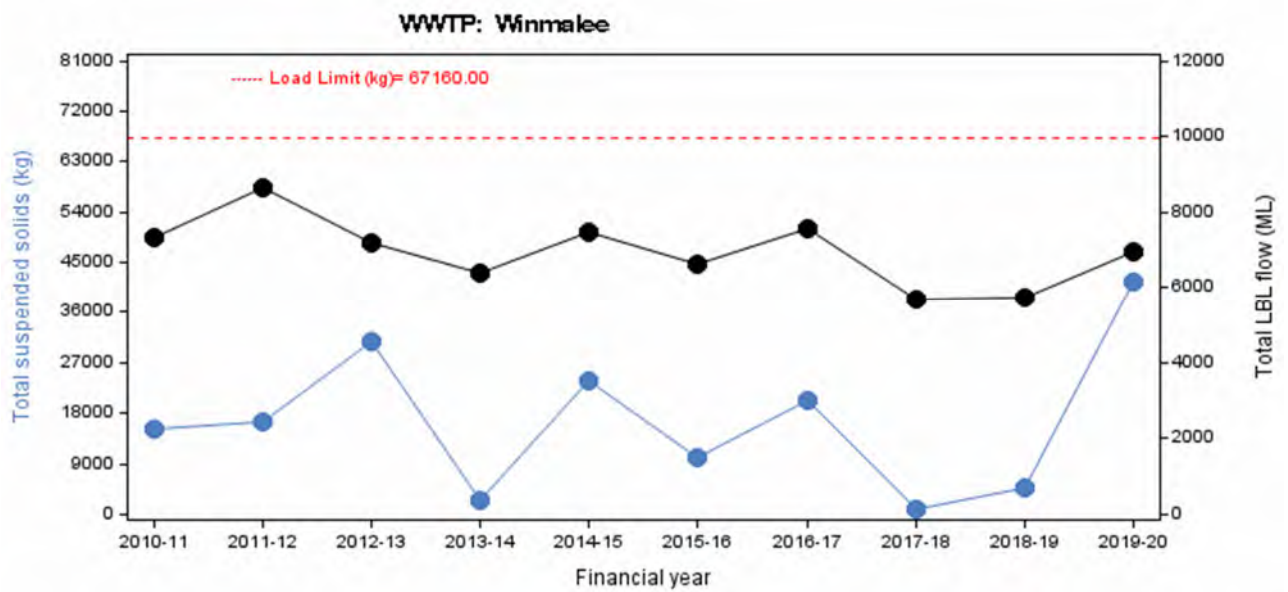
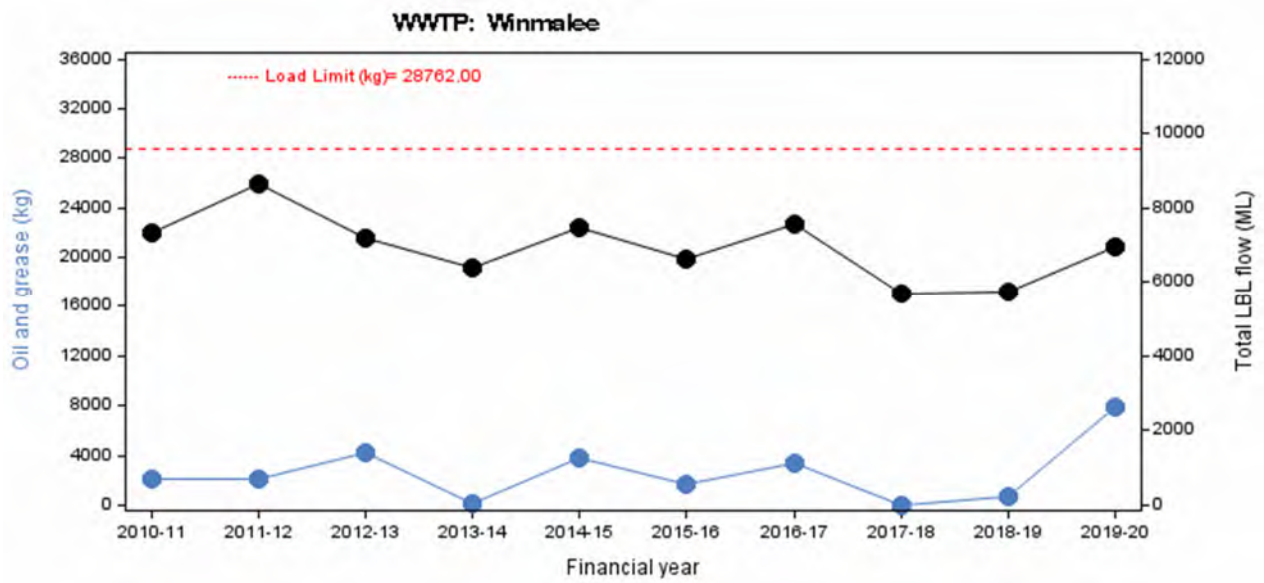
Note: Statistical test was not conducted because >90% of results were below the detection limit.

Discharge load: Nutrients



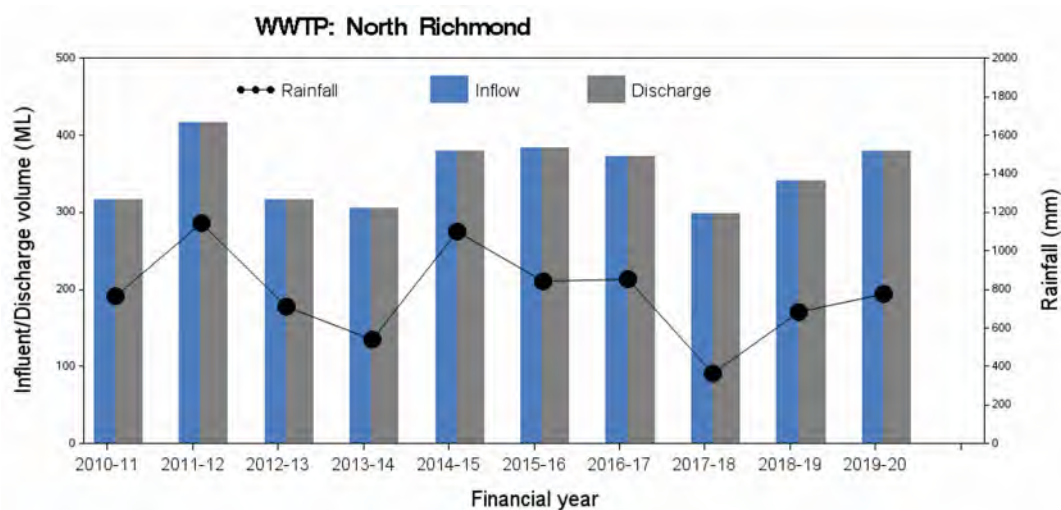
Discharge load: Major conventional analytes



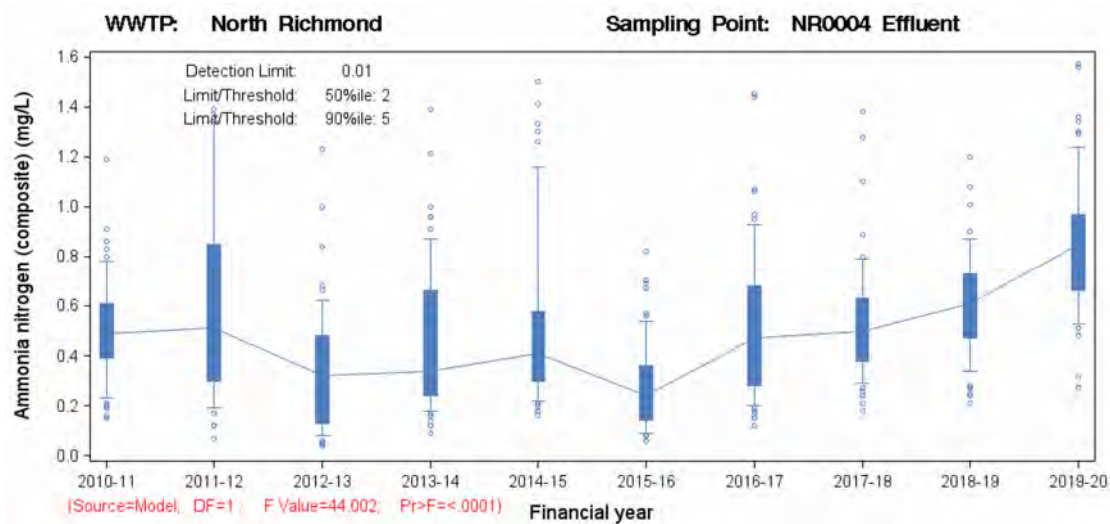
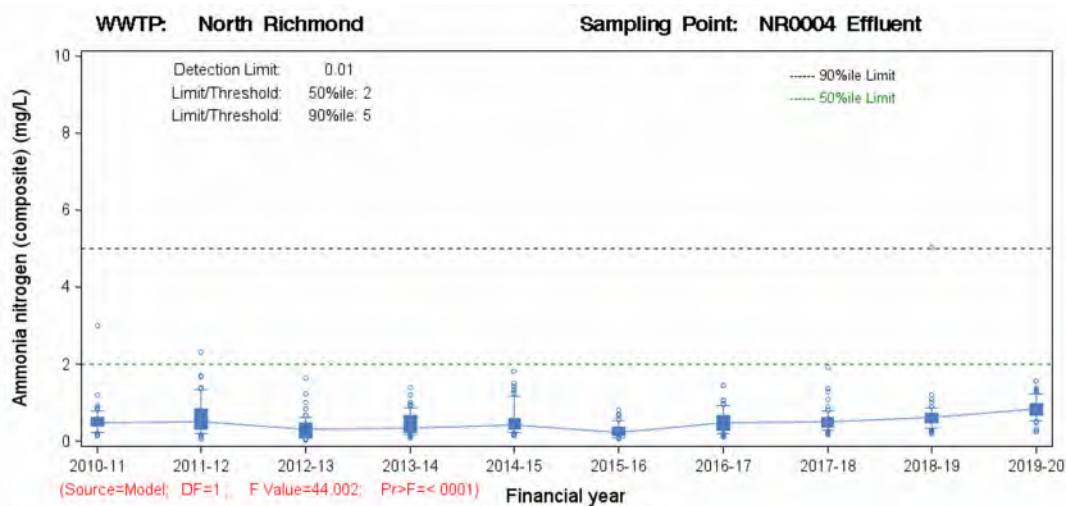


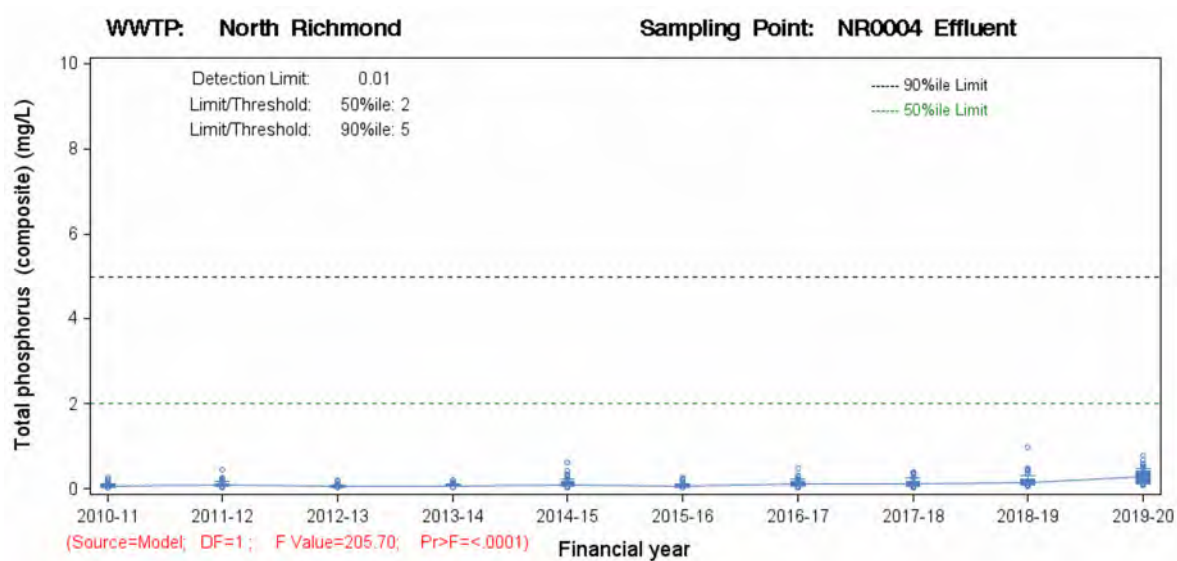
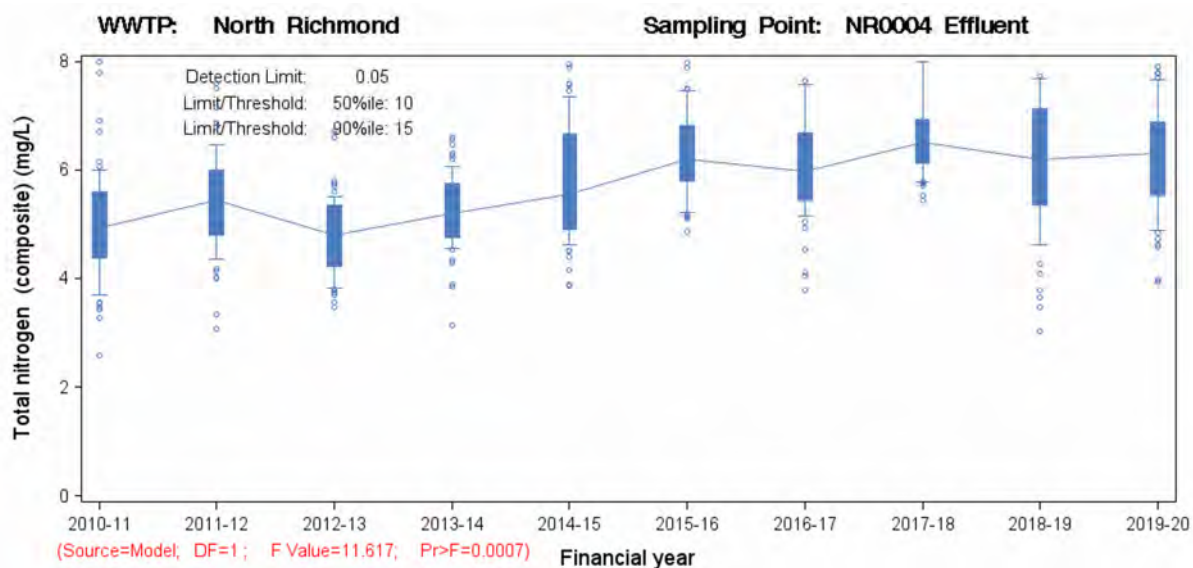
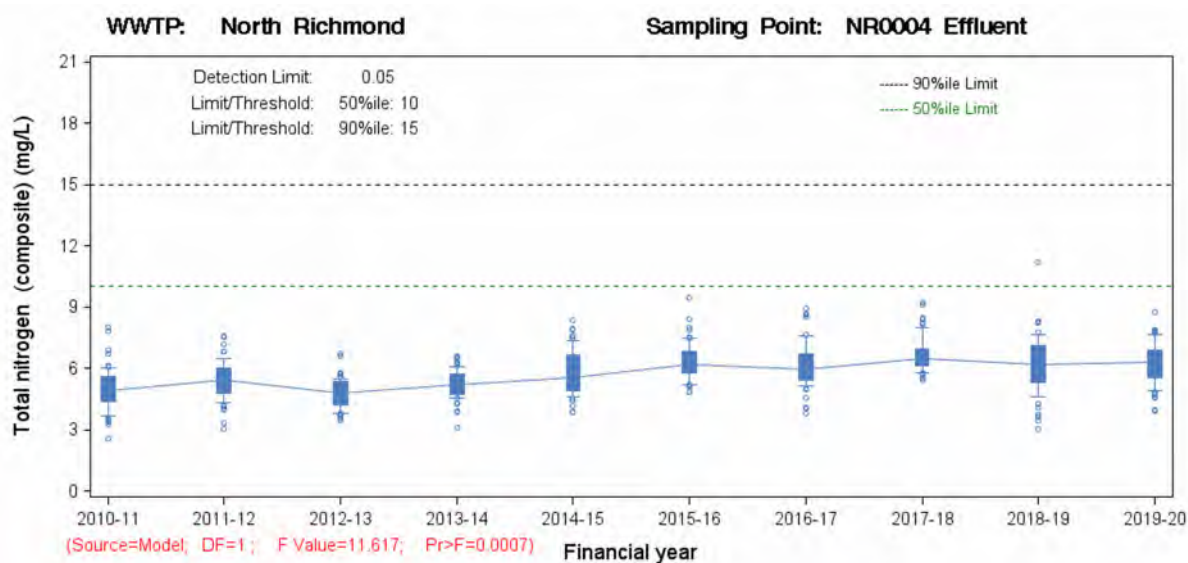
North Richmond WWTP

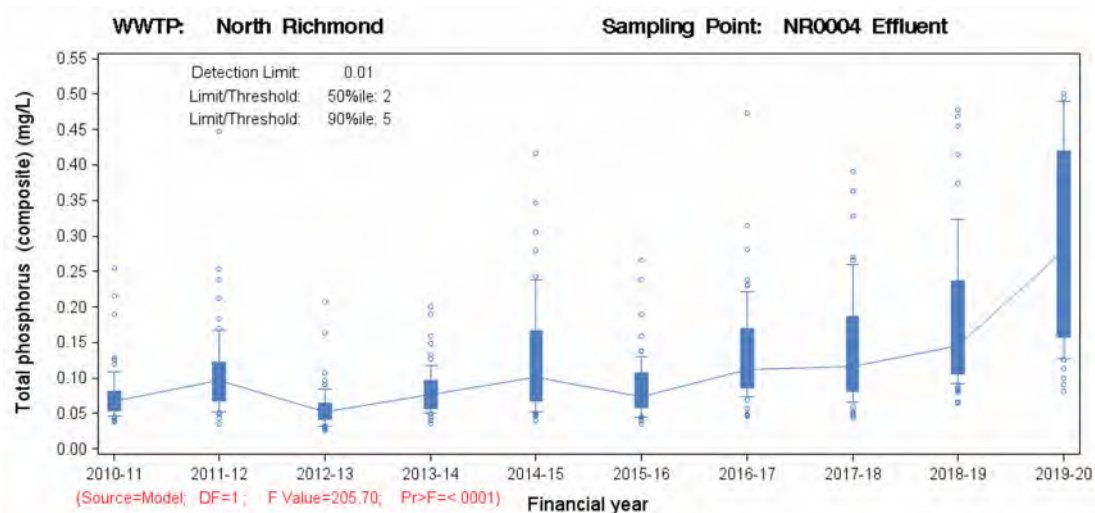
Discharge volume and rainfall



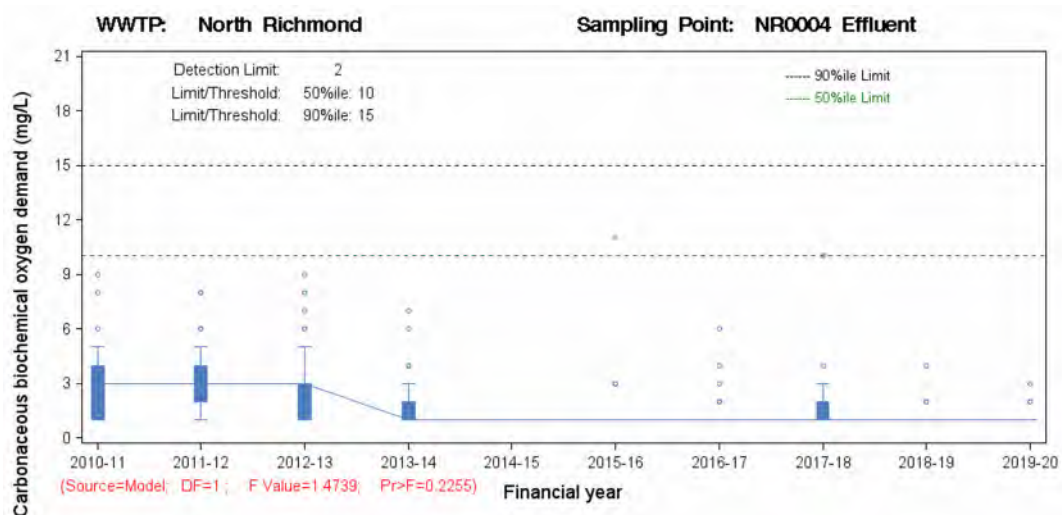
Discharge quality: Nutrients



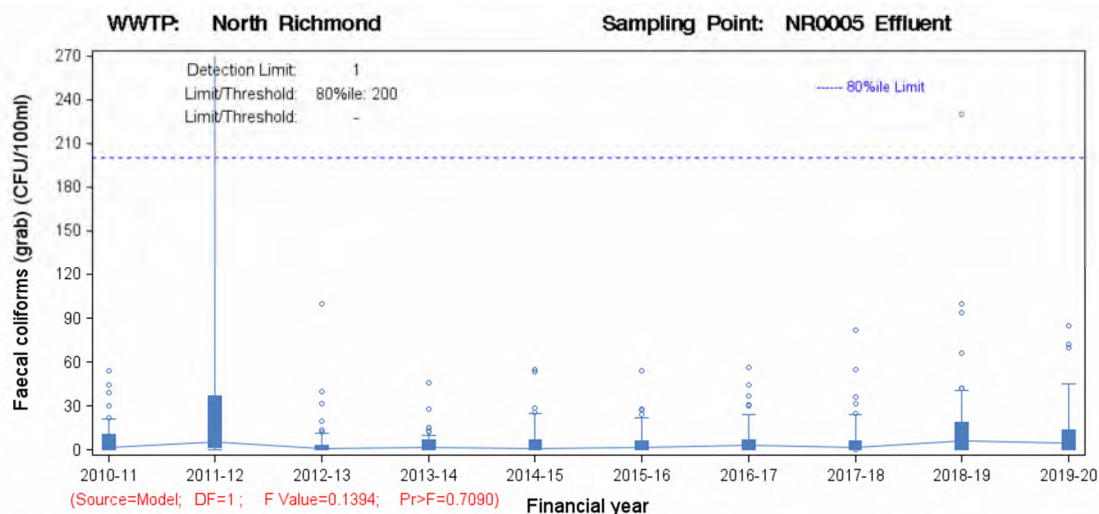


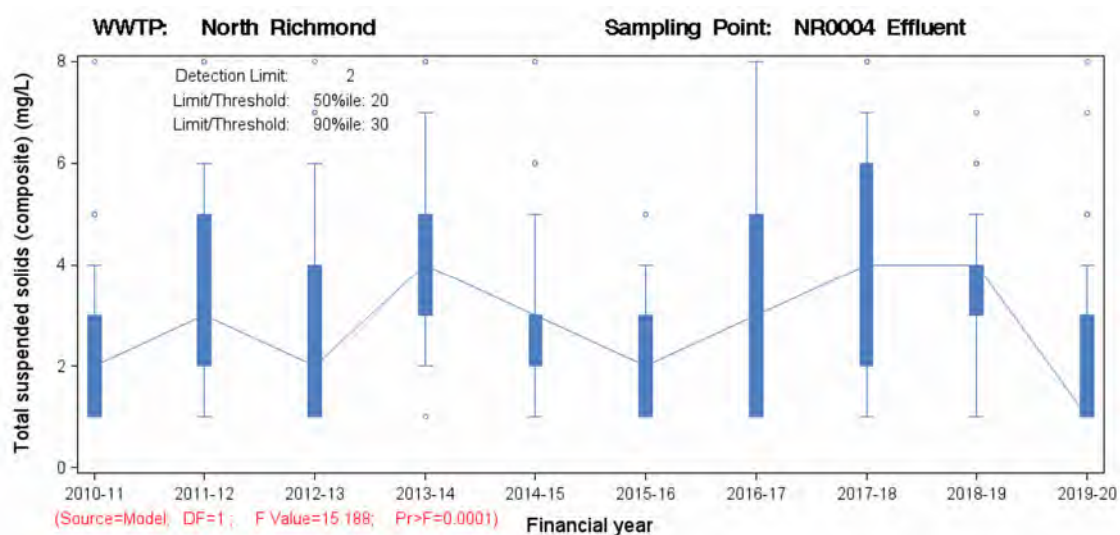
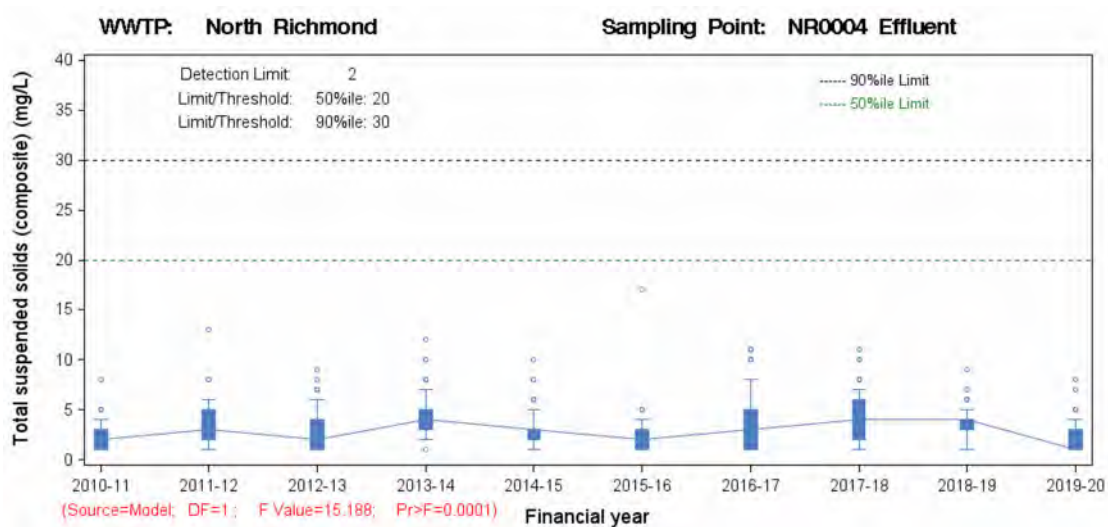


Discharge quality: Major conventional analytes

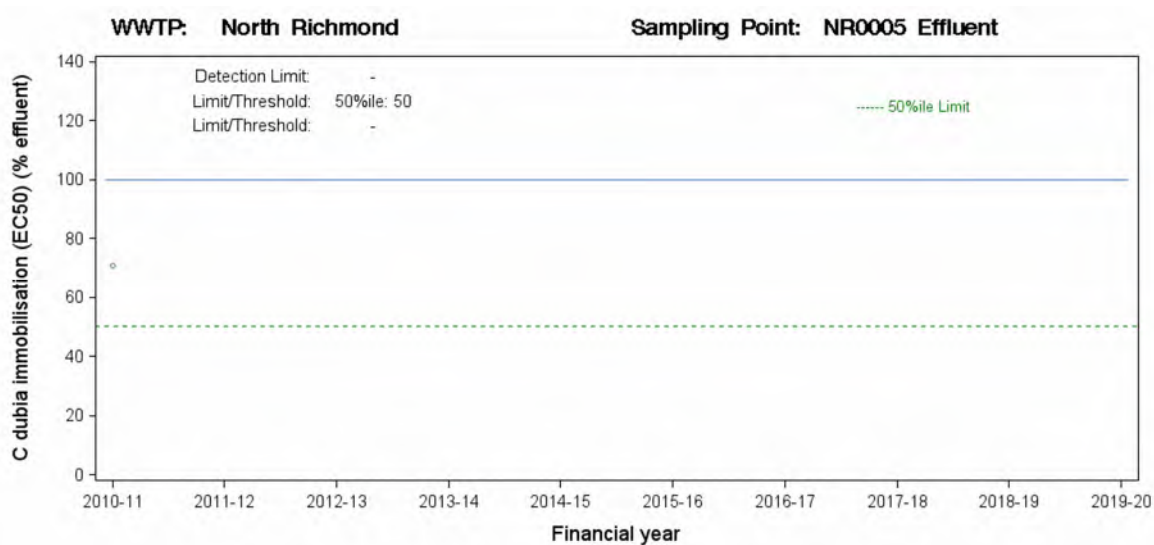


Note: Statistical test was based on 2019-20 data with previous five years data (2014-2019) due to lab method change in 2014-15.

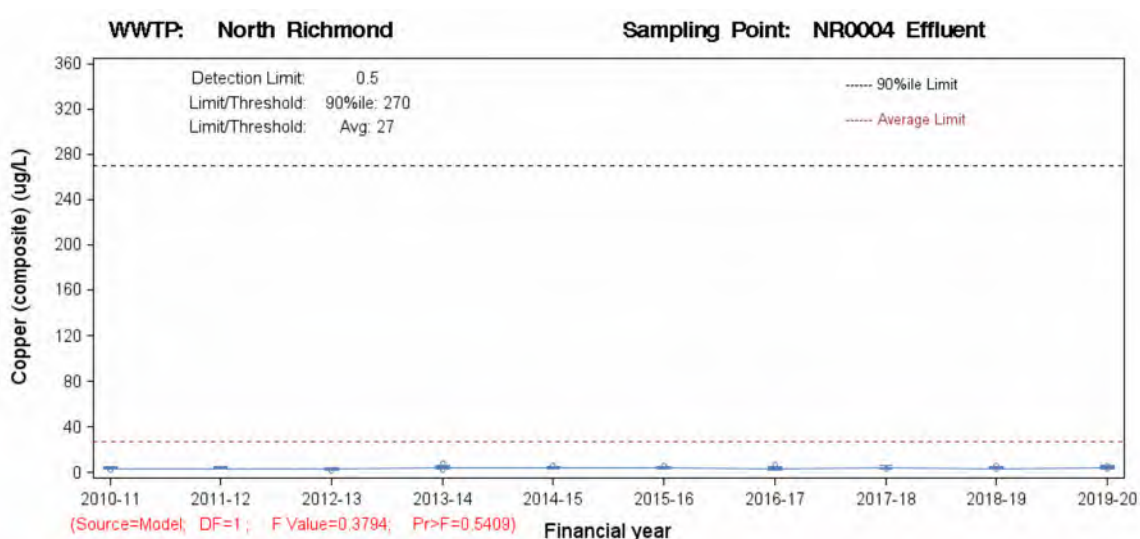
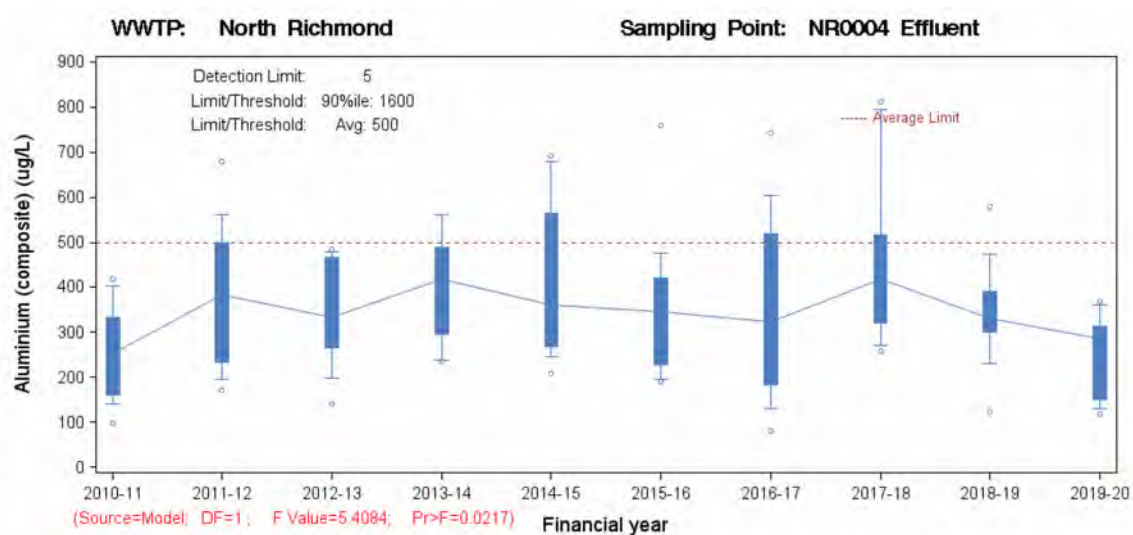
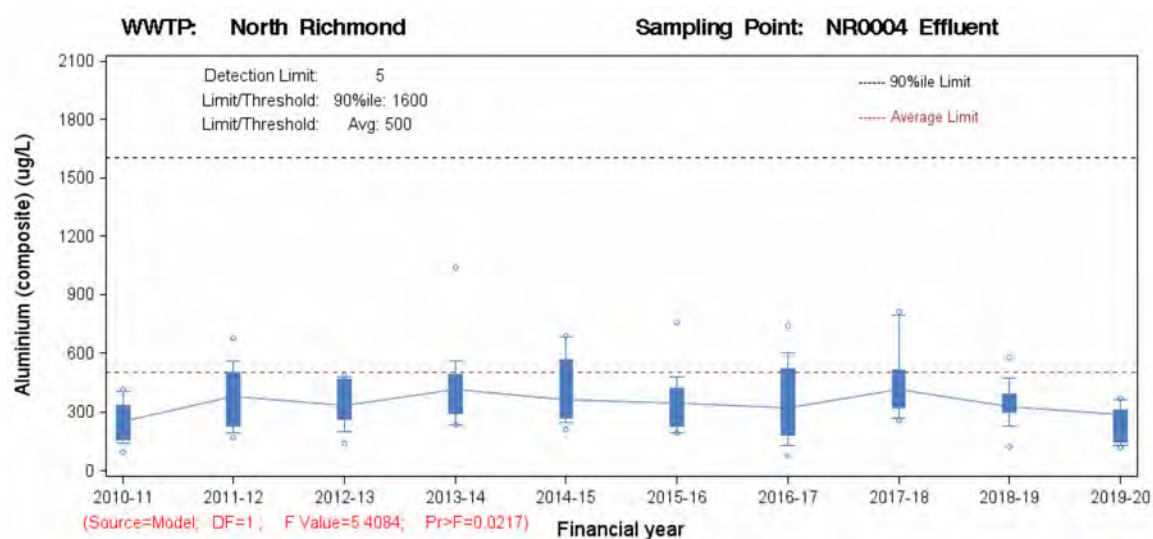




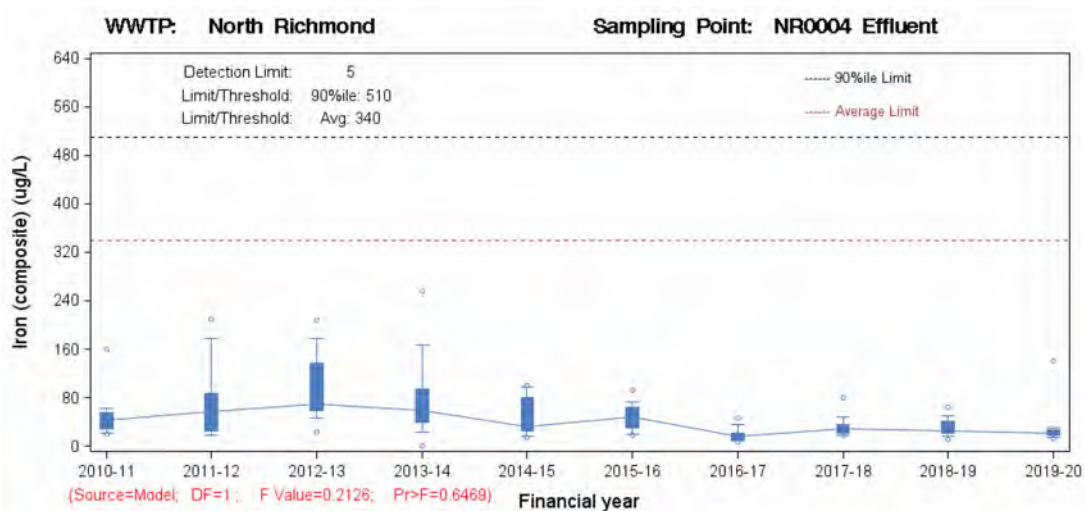
Discharge quality: Toxicity



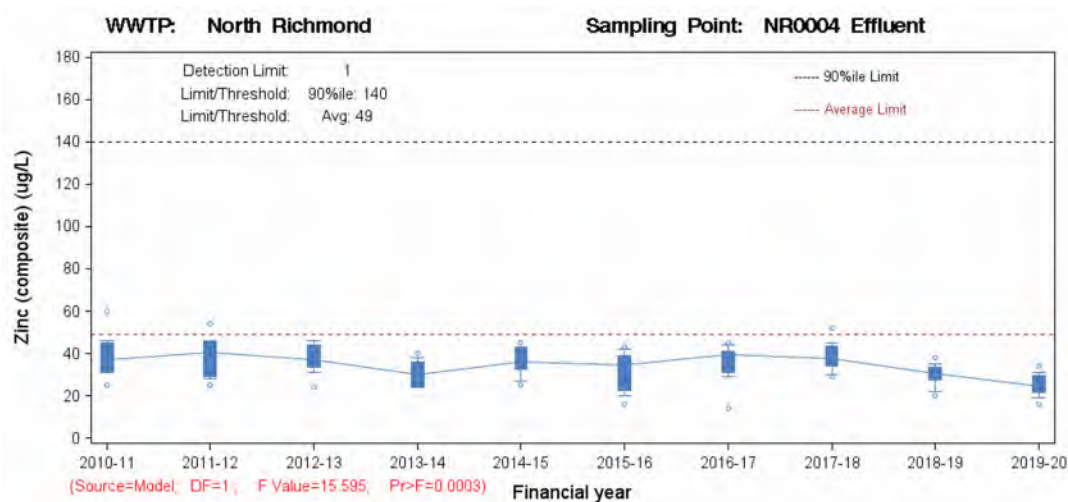
Note: Statistical test was not conducted because >90% of results were recorded at 100% survival for *Ceriodaphnia dubia*.



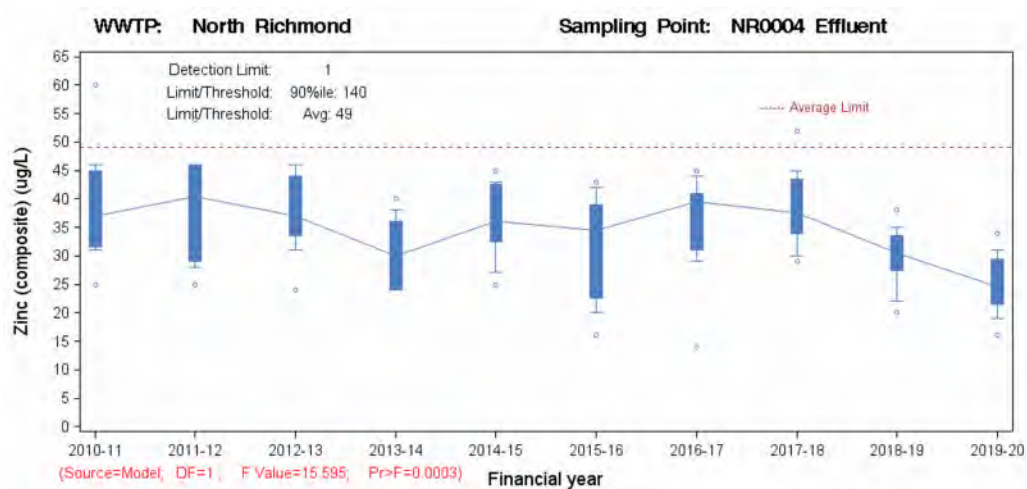
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.



Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

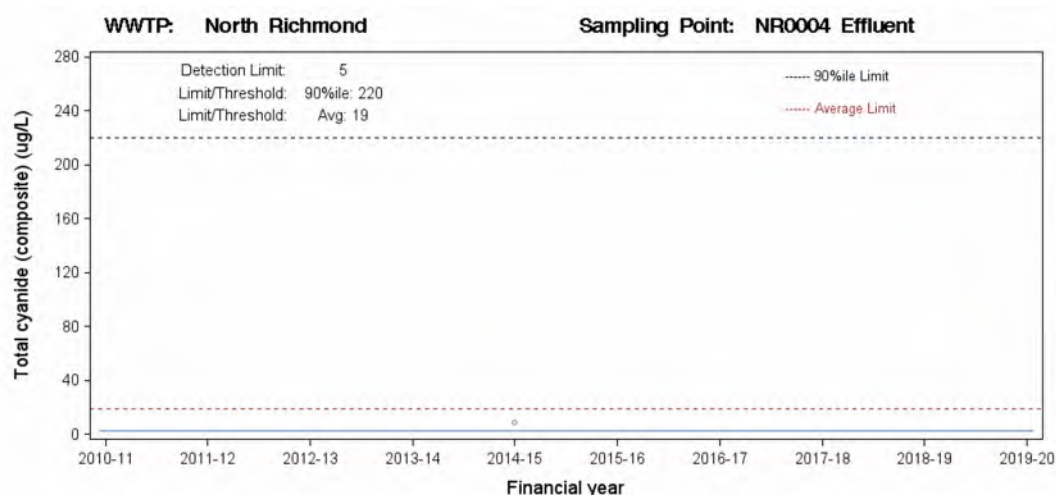


Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

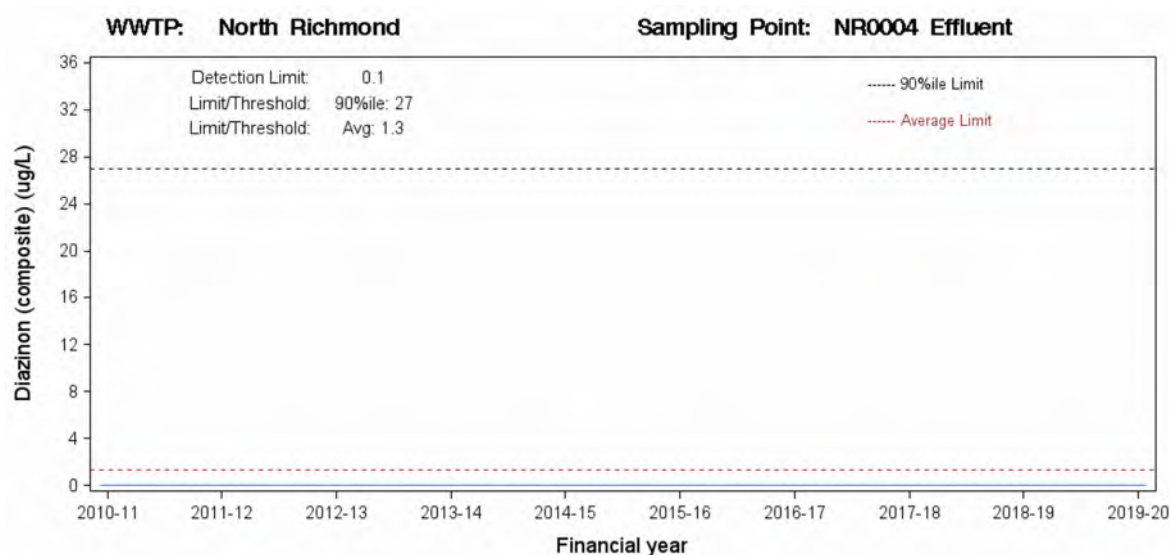


Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

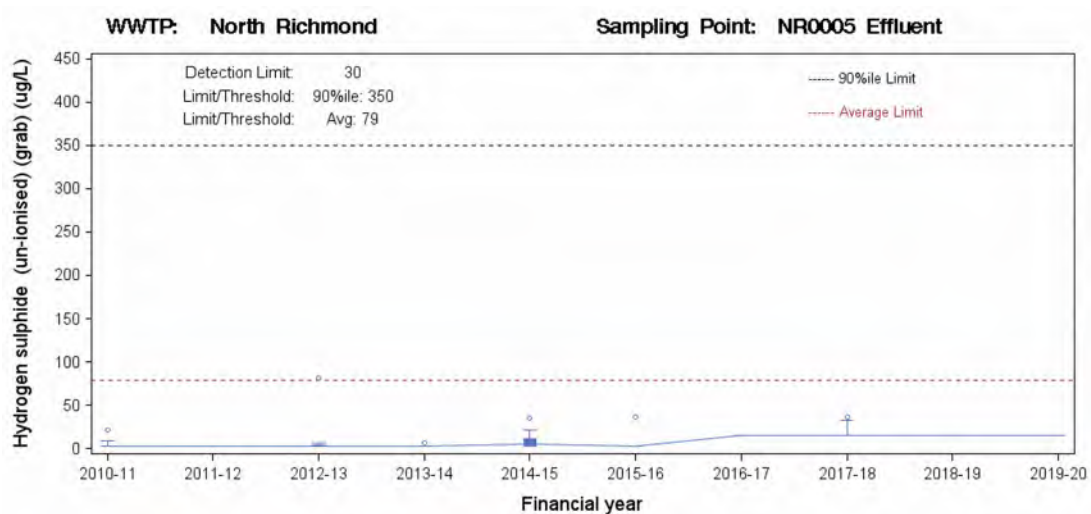
Discharge quality: Other chemicals and organics (including pesticides)



Note: Statistical test was not conducted because >90% of results were below the detection limit.

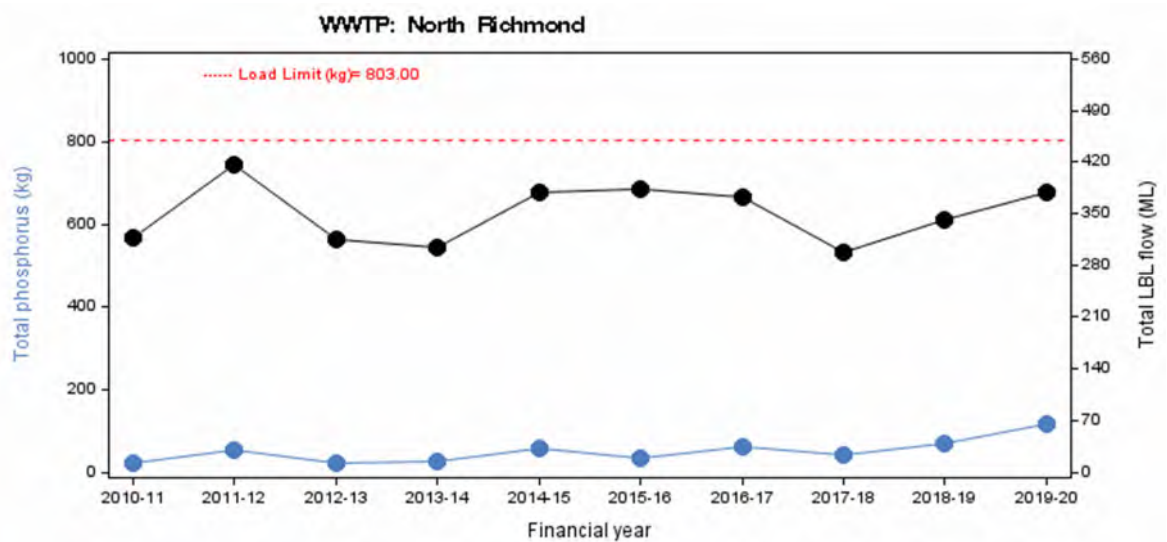
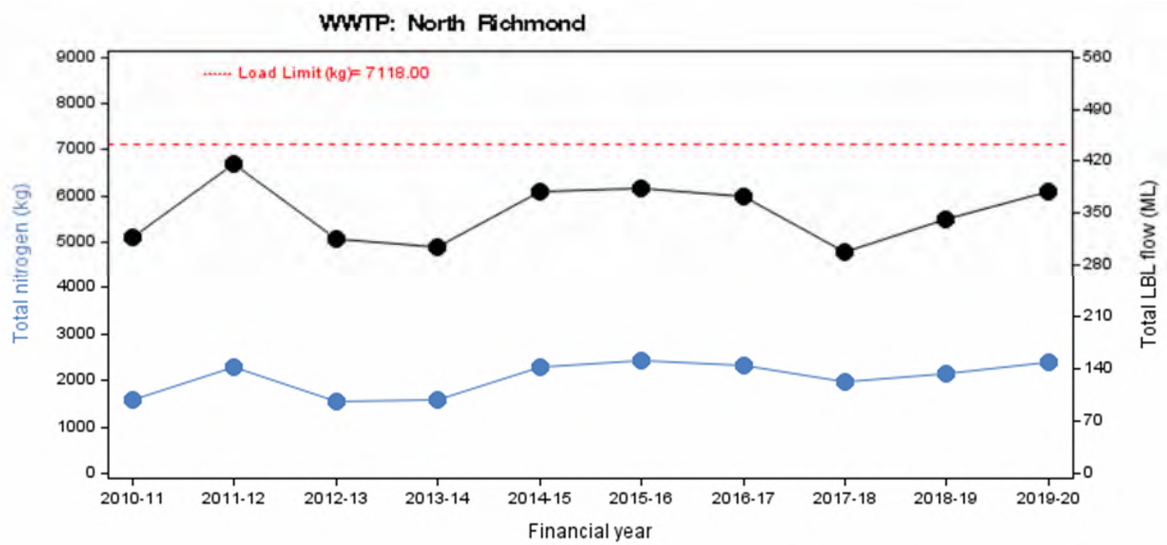


Note: Statistical test was not conducted because >90% of results were below the detection limit.

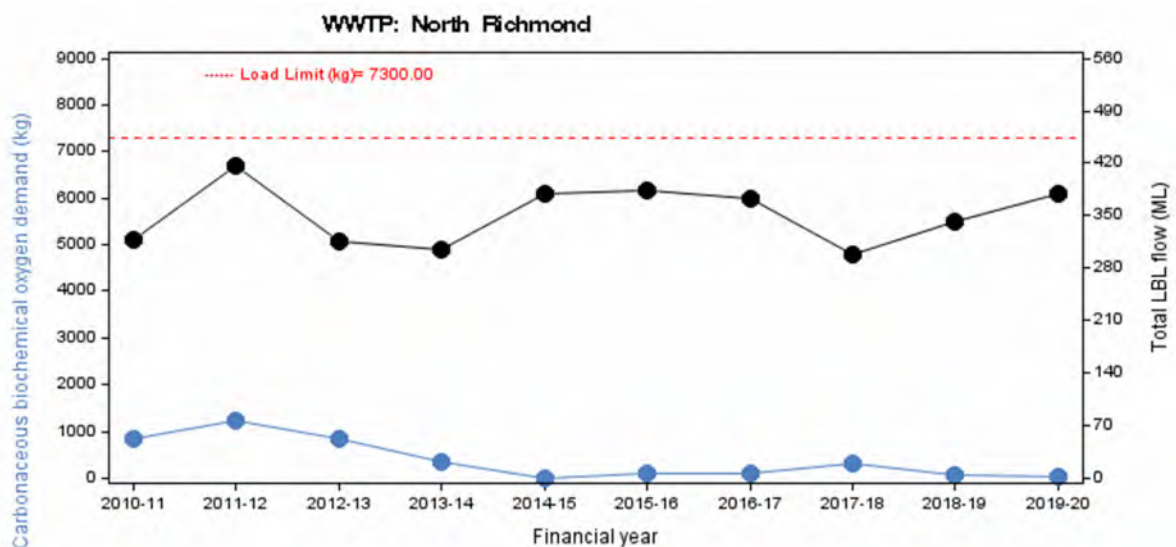


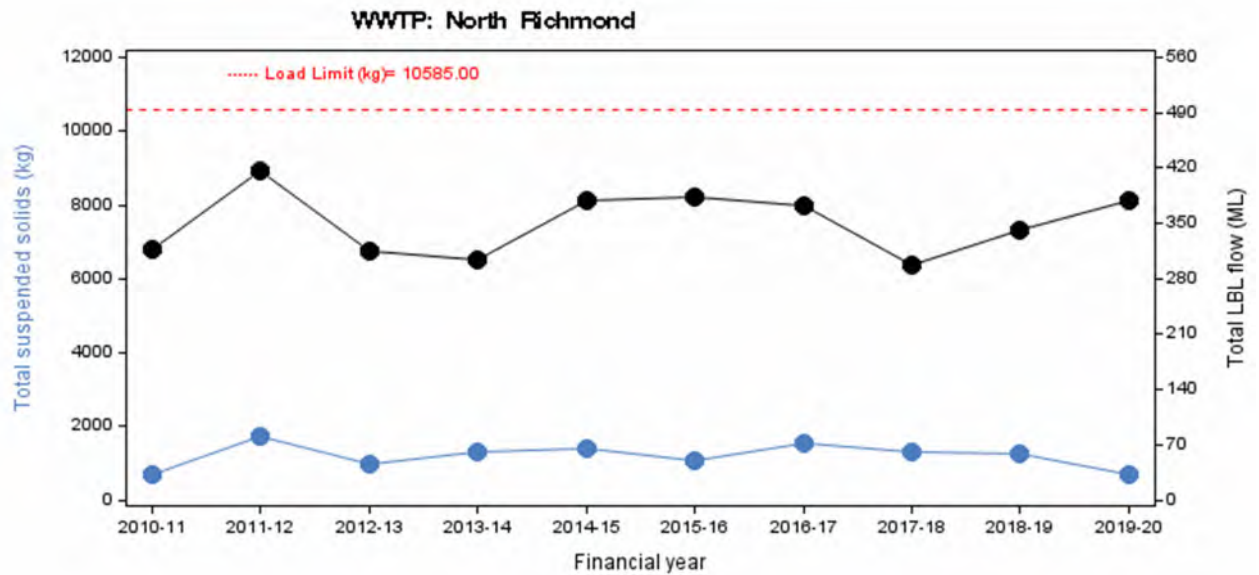
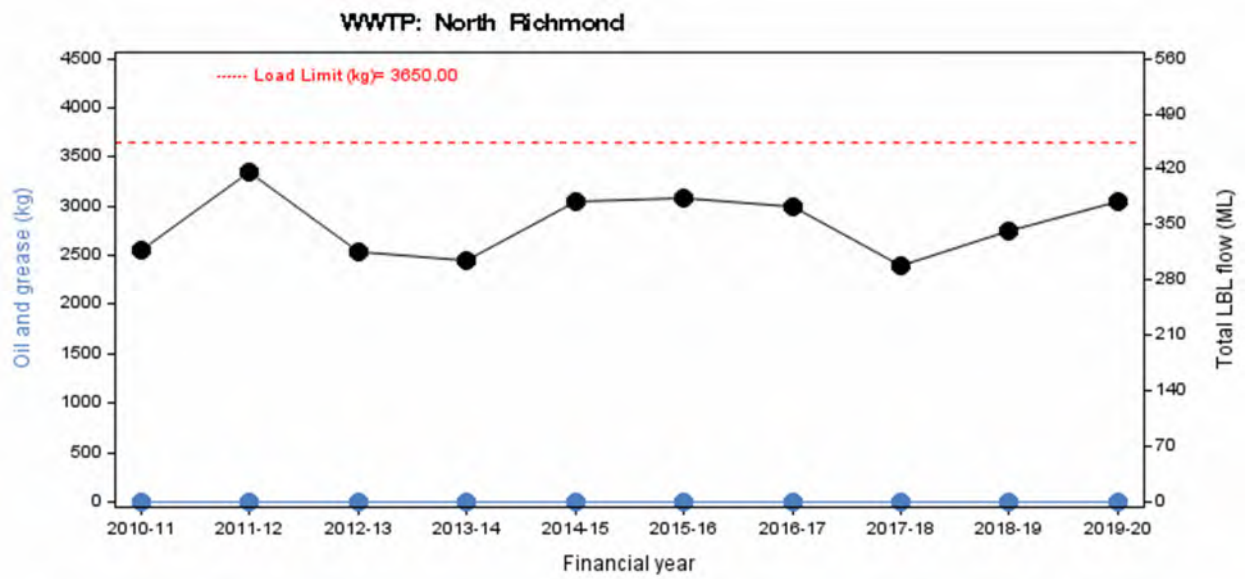
Note: 2019-20 data was compared with previous three years data (2016-2019) due to lab method change in 2016-17.
Statistical test was not conducted because >90% of results were below the detection limit.

Discharge load: Nutrients



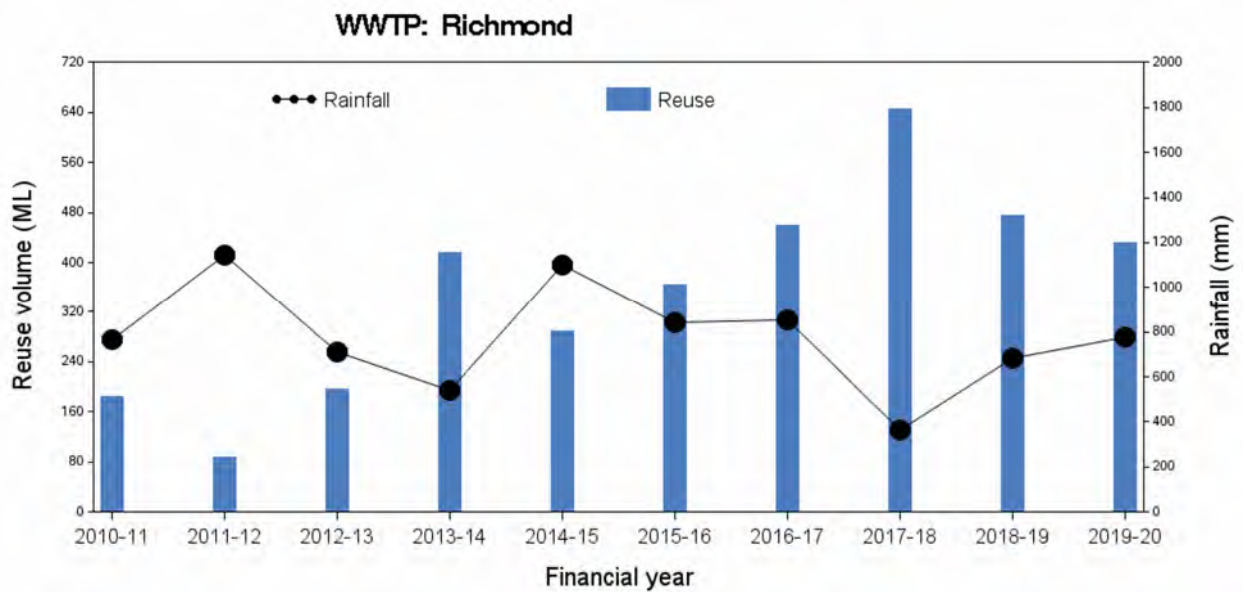
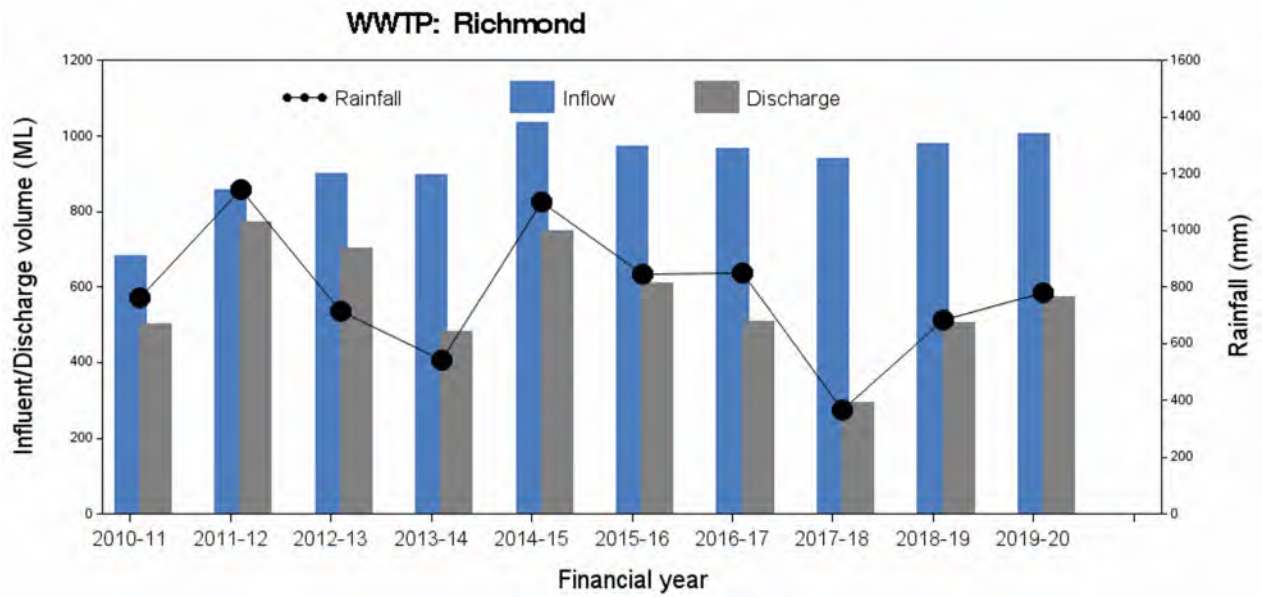
Discharge load: Major conventional analytes



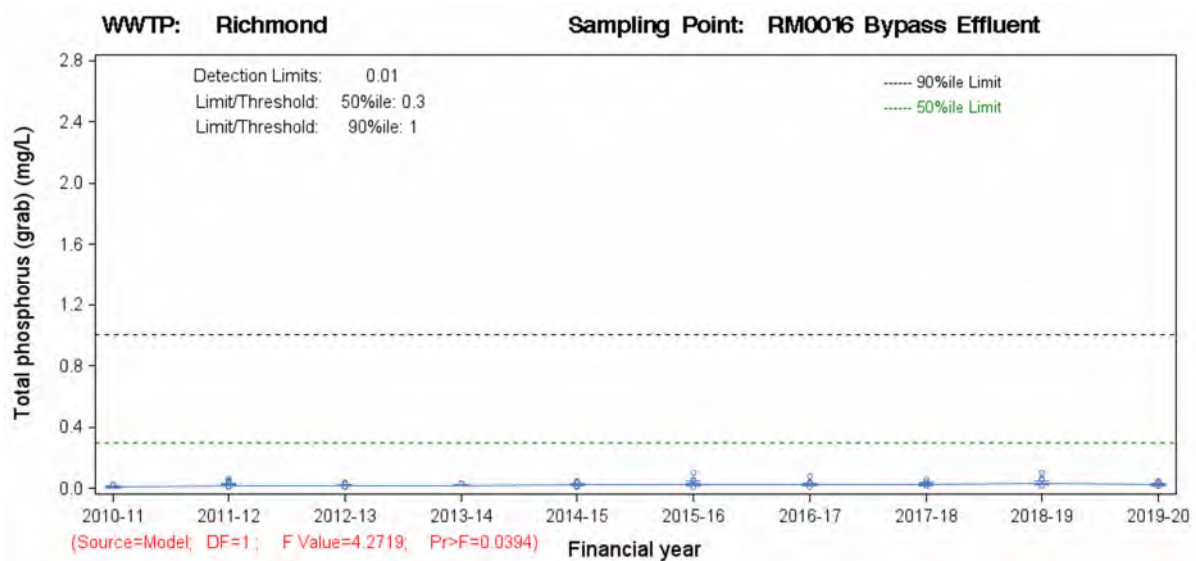
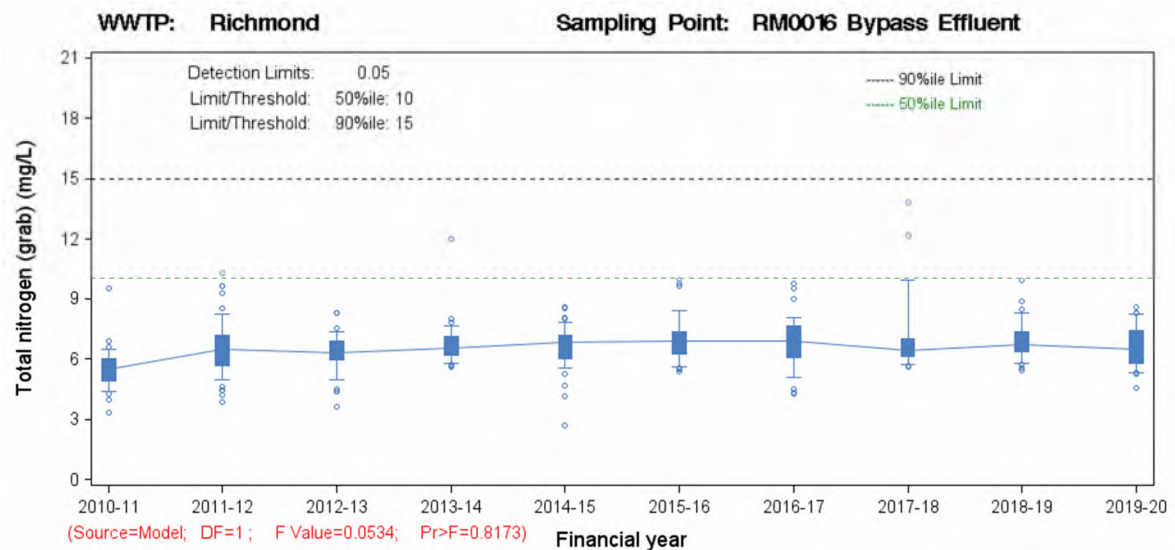
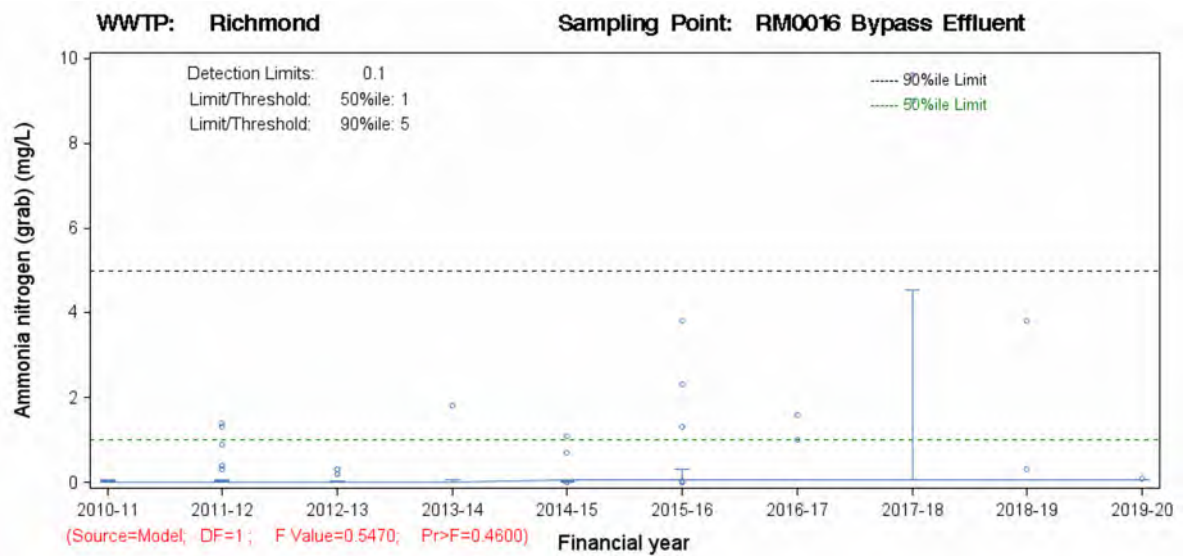


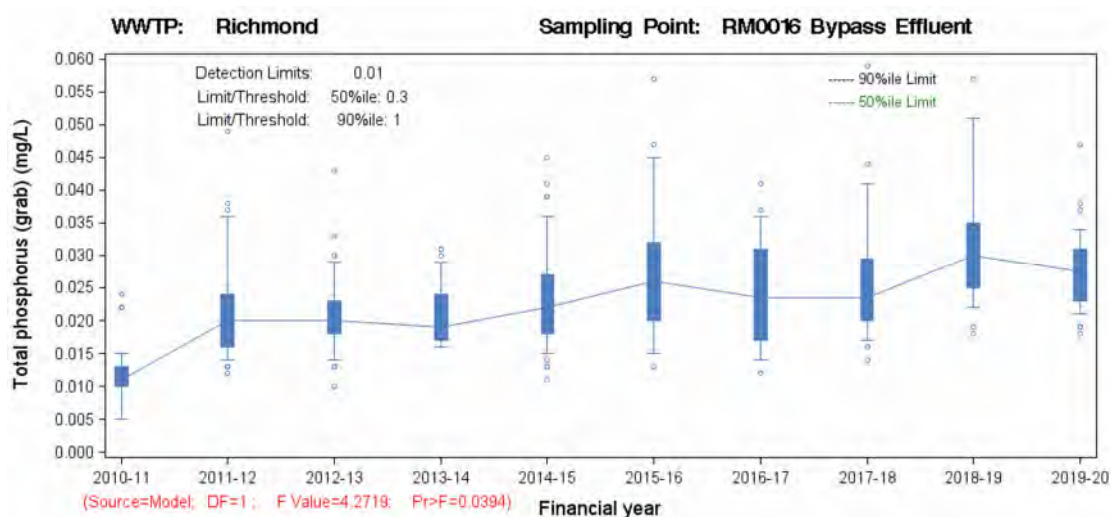
Richmond WWTP

Discharge volume and rainfall

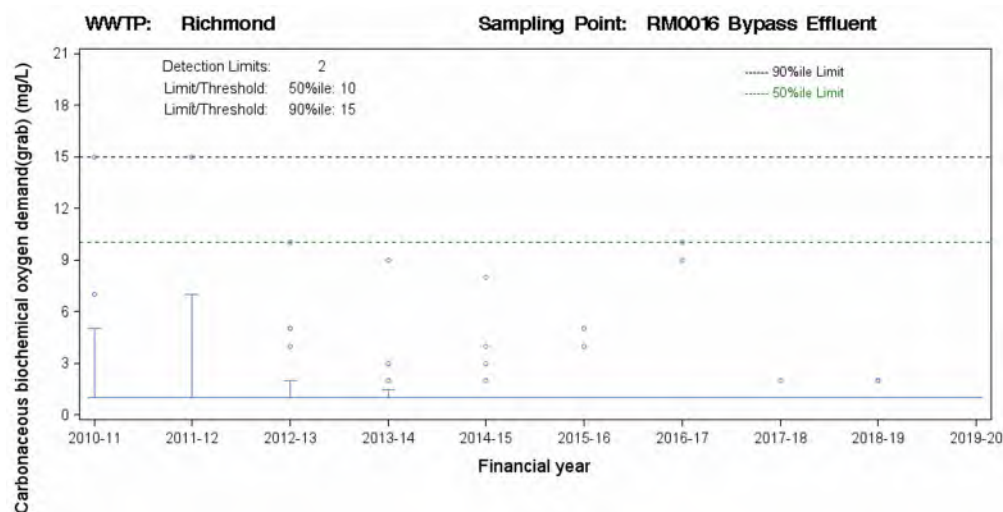


Discharge quality: Nutrients (RM0016 Bypass Effluent)

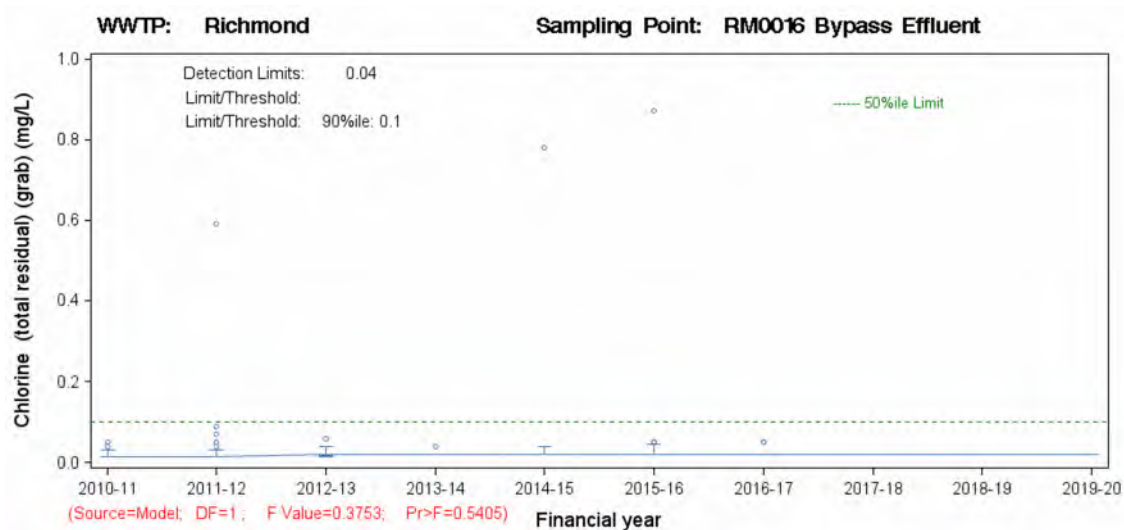


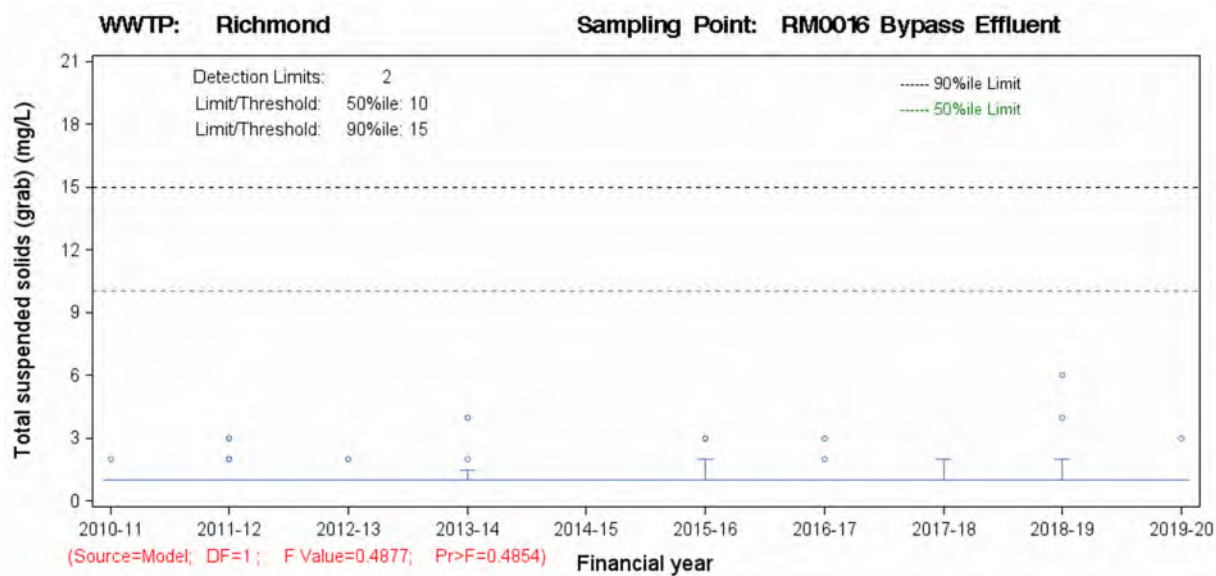
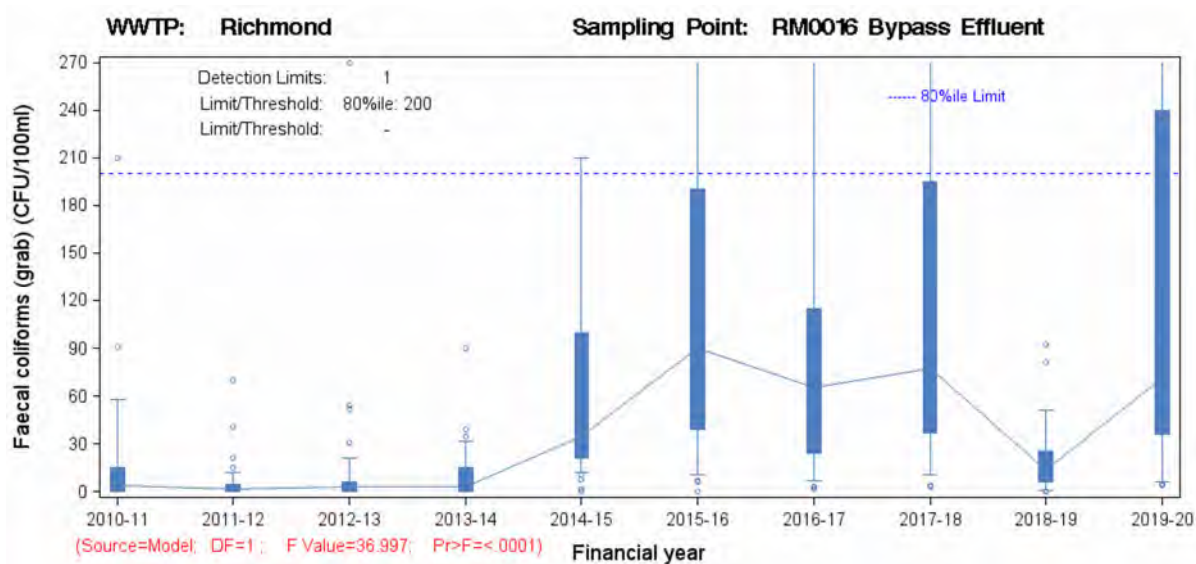
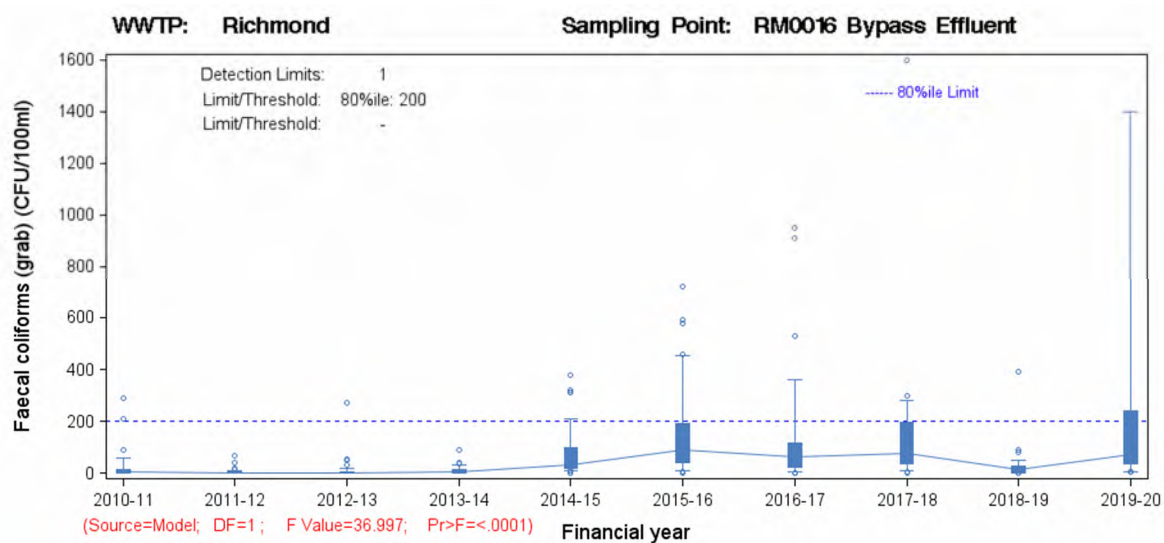


Discharge quality: Major conventional analytes (RM0016 Bypass Effluent)

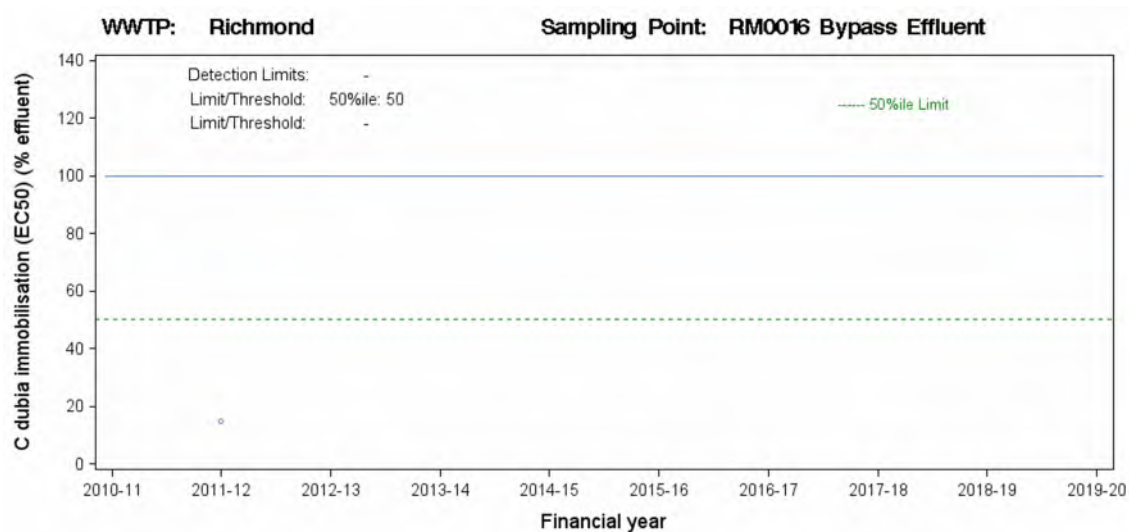


Note: 2019-20 data was compared with previous five years data (2014-2019) due to lab method change in 2014-15. Statistical test was not conducted because >90% of results were below the detection limit.



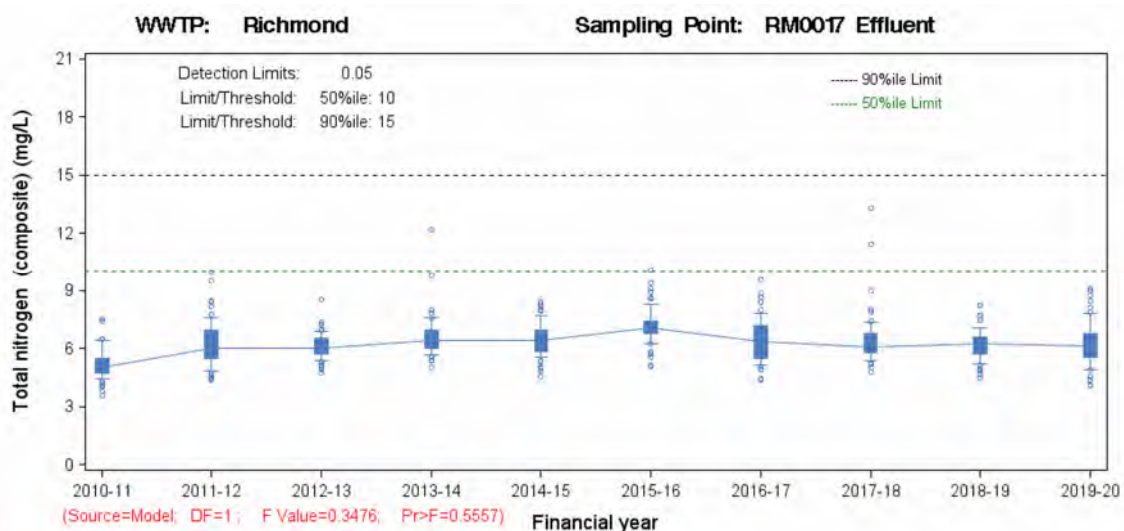
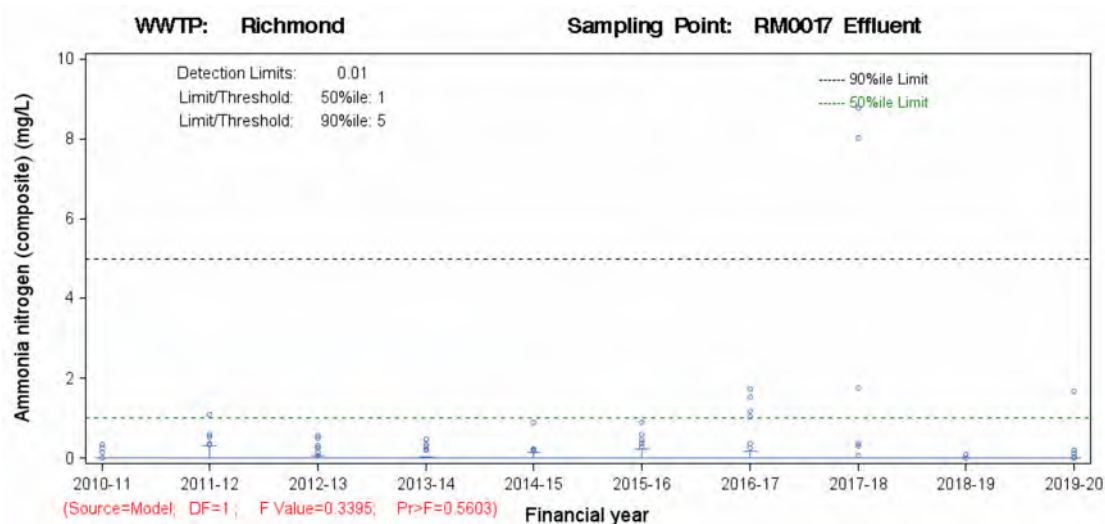


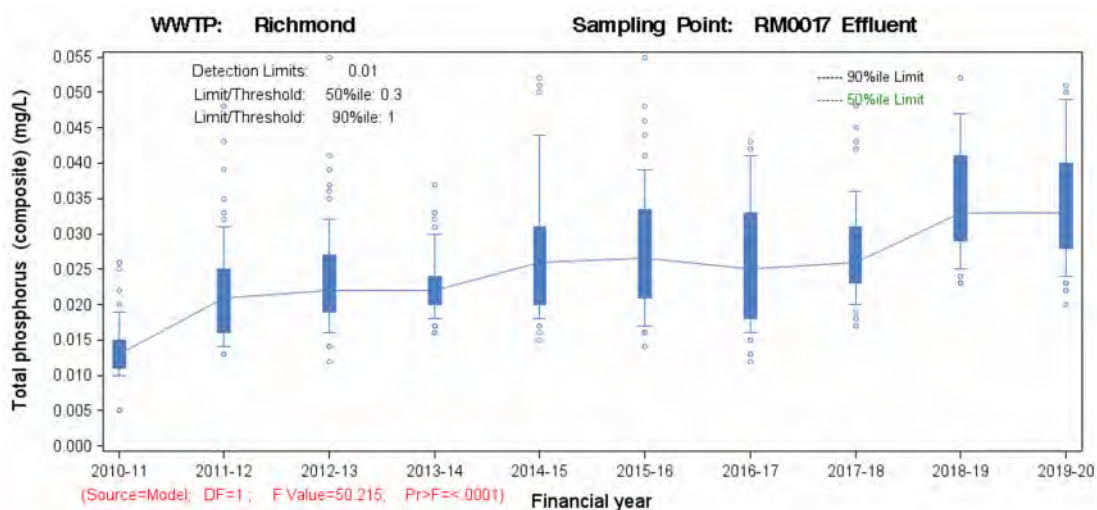
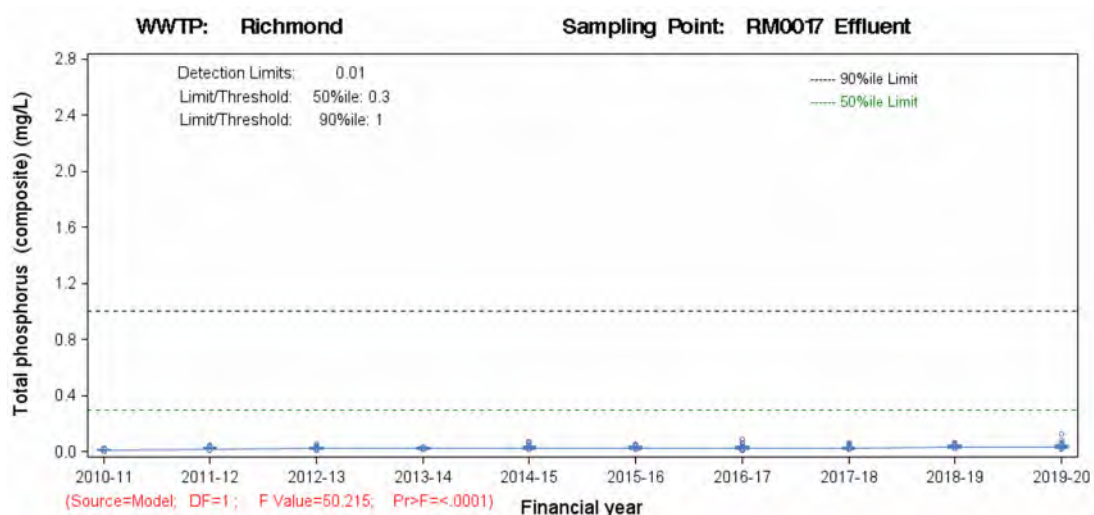
Discharge quality: Toxicity (RM0016 Bypass Effluent)



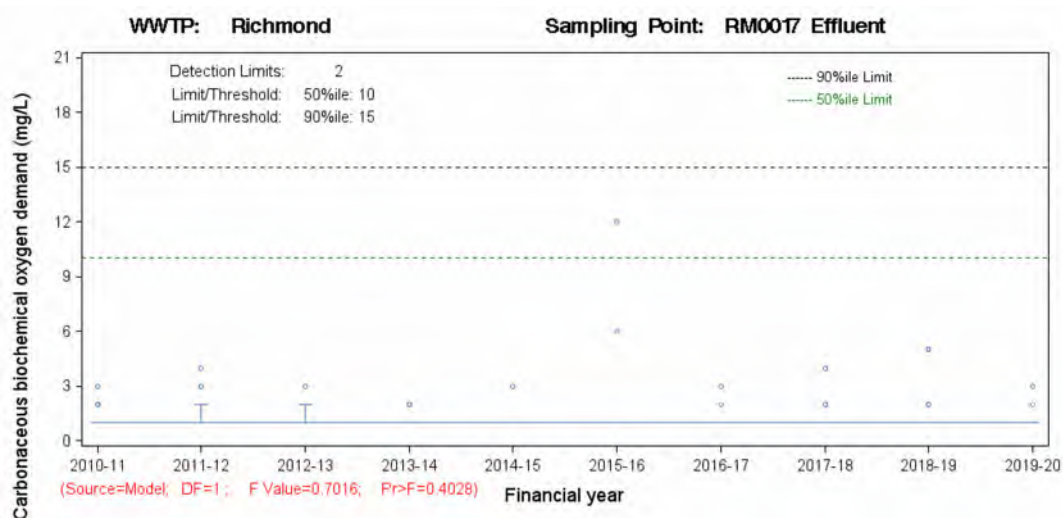
Note: Statistical test was not conducted because >90% of results were recorded at 100% survival for *Ceriodaphnia dubia*.

Discharge quality: Nutrients (RM0017 Effluent)

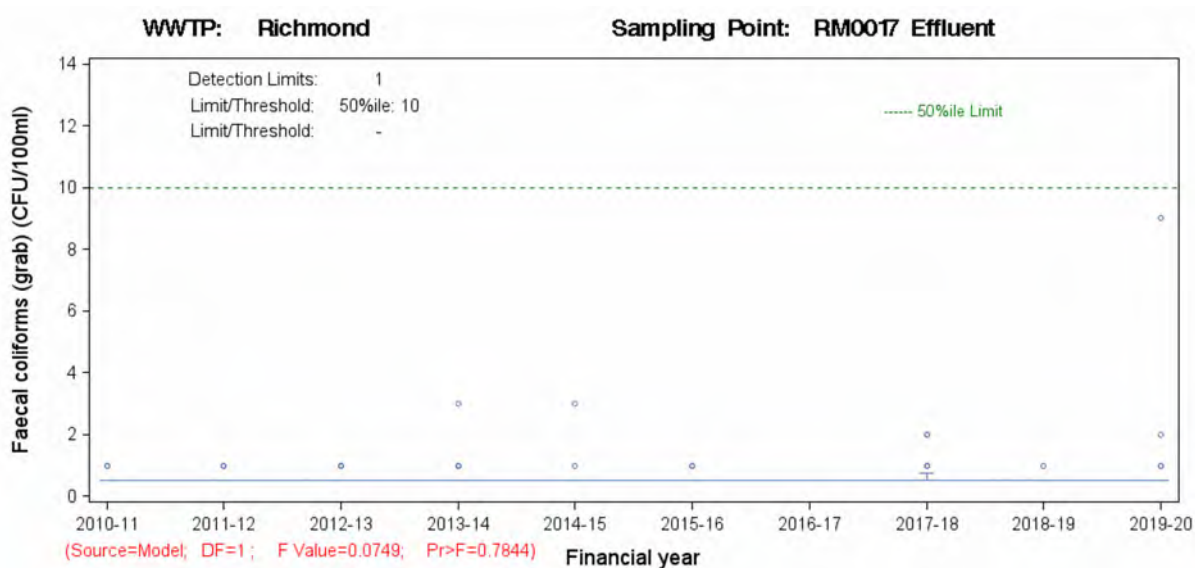
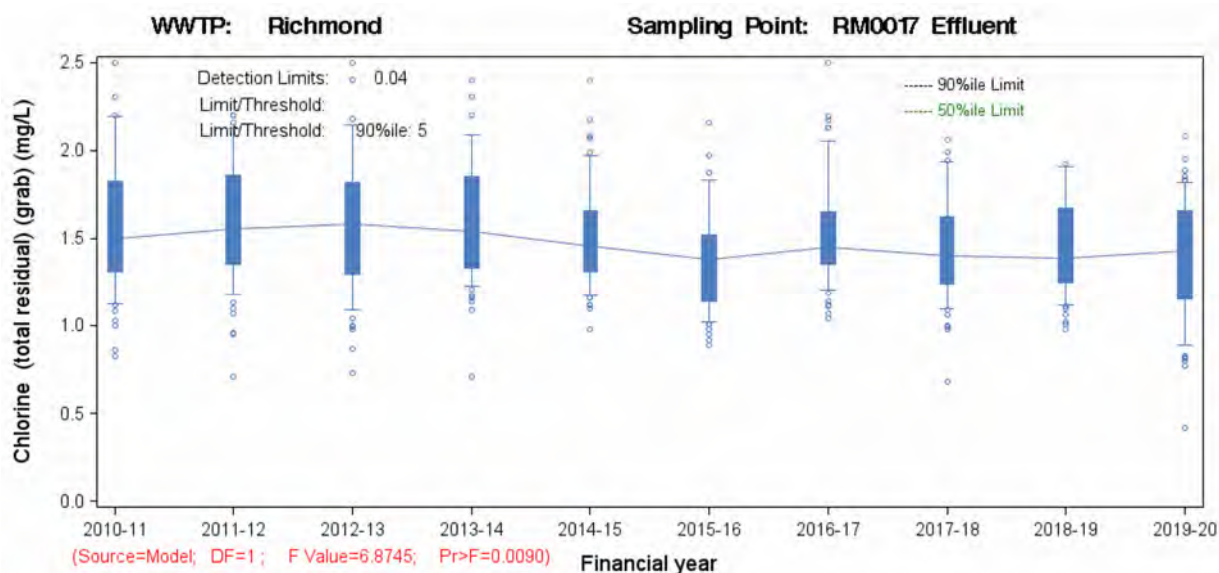
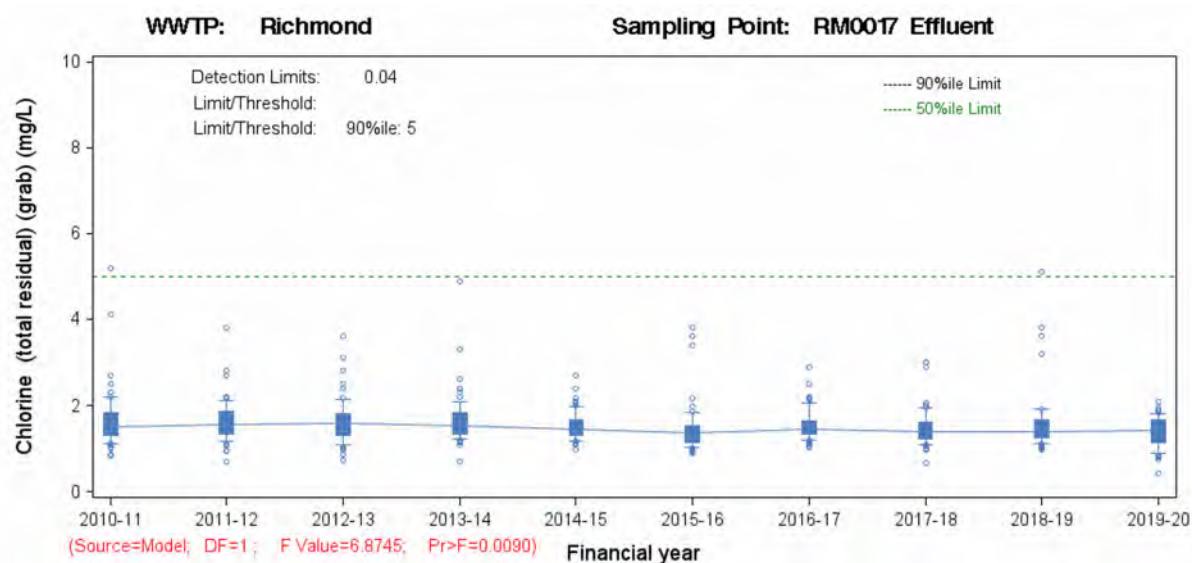


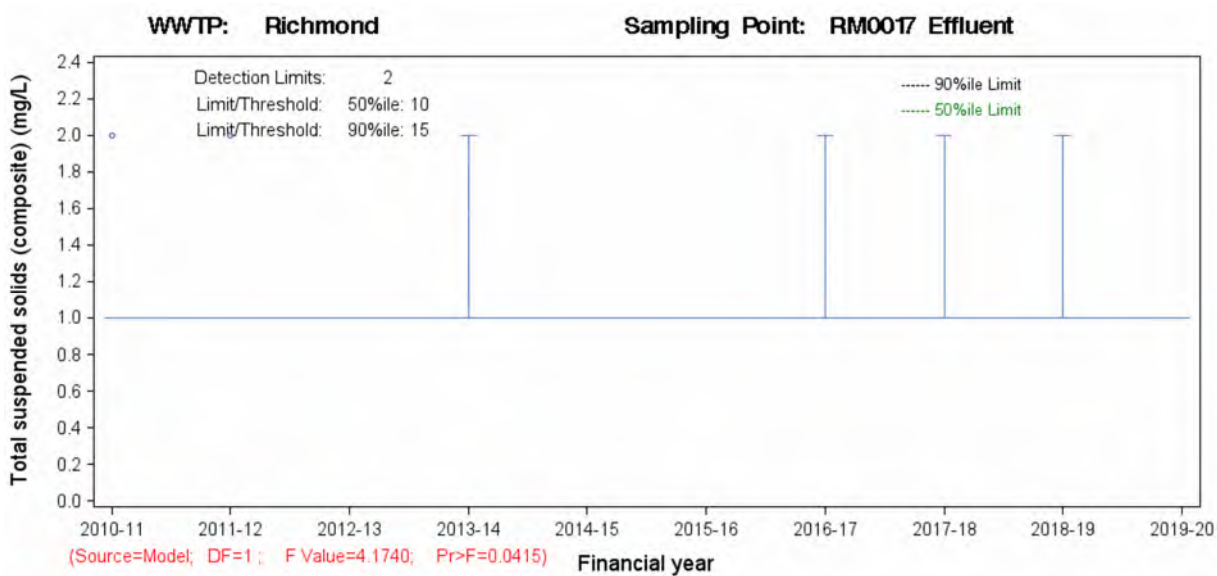
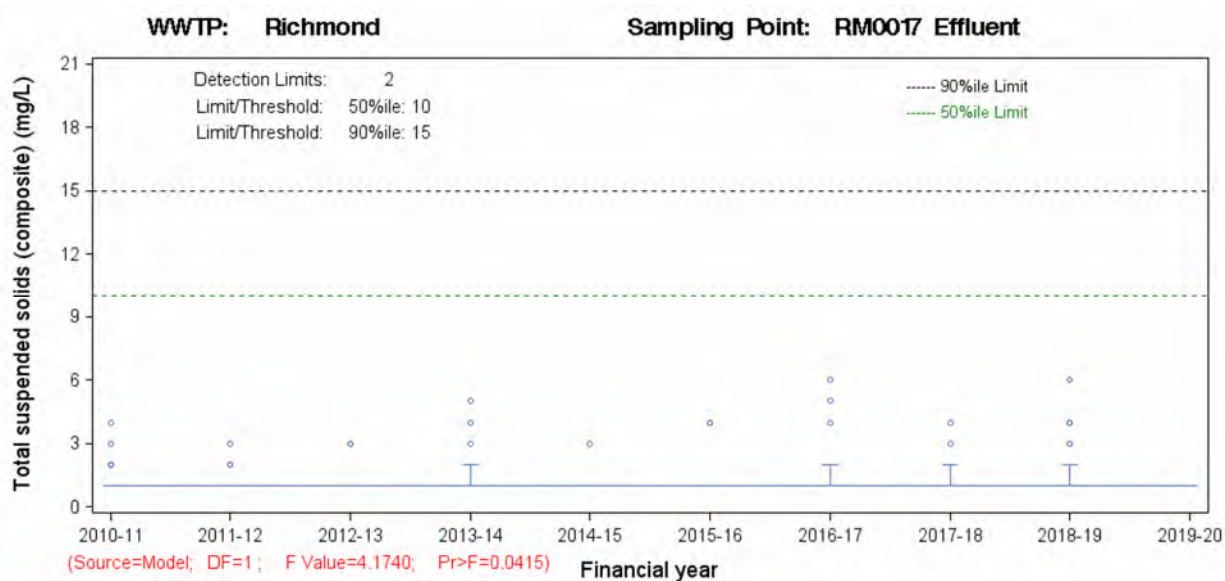


Discharge quality: Major conventional analytes (RM0017 Effluent)

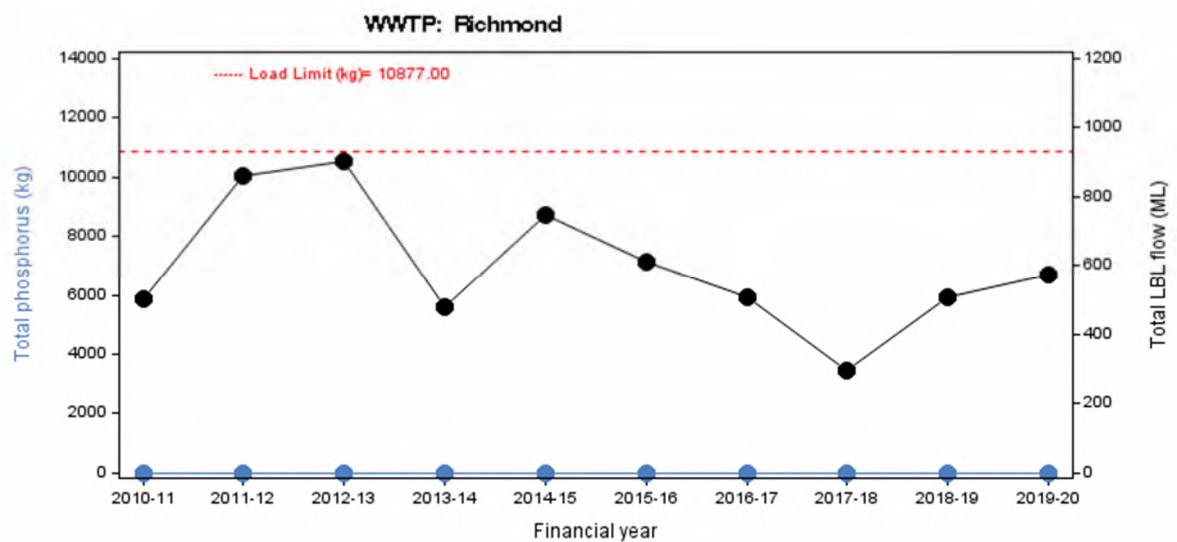
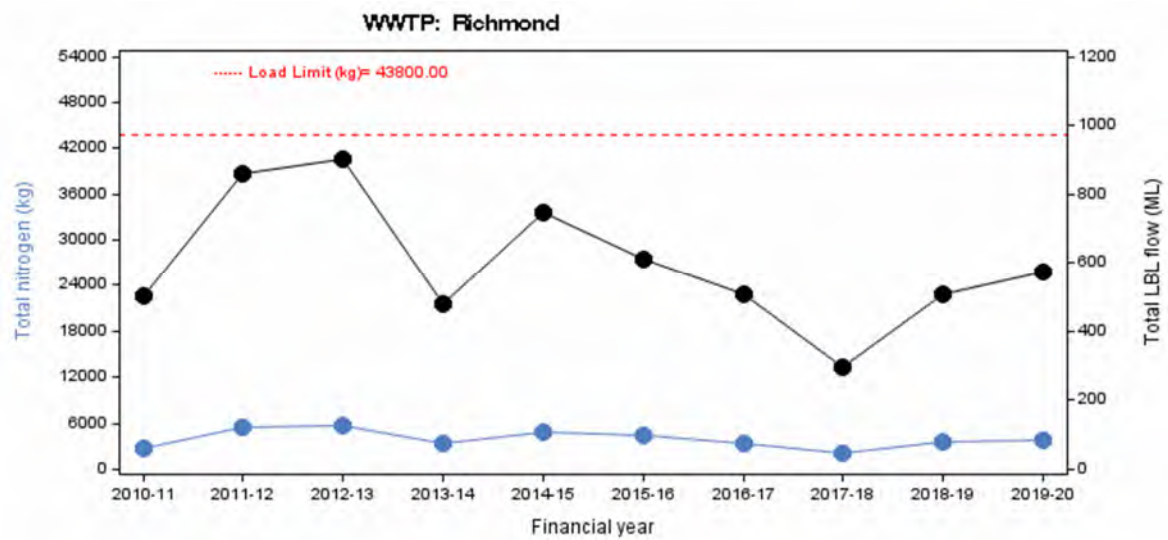


Note: Statistical test was based on 2019-20 data with previous five years data (2014-2019) due to lab method change in 2014-15.

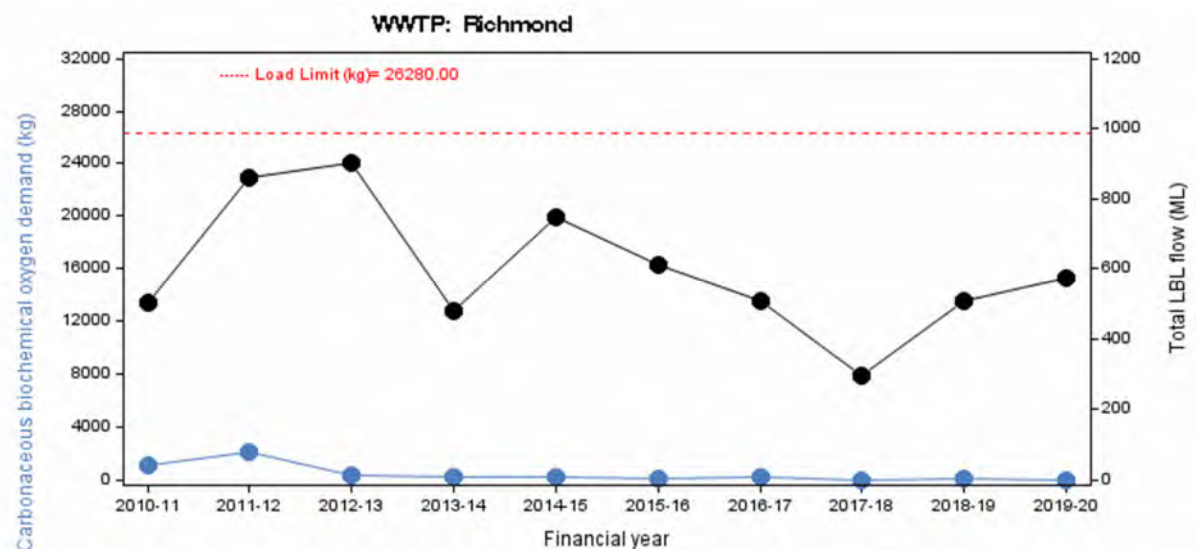


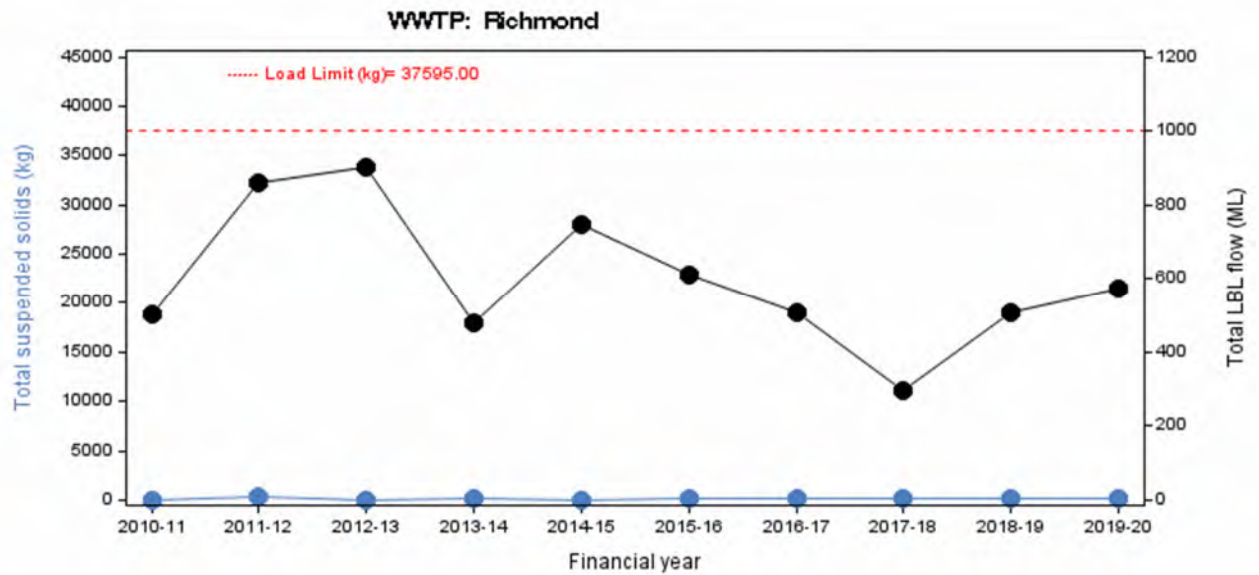
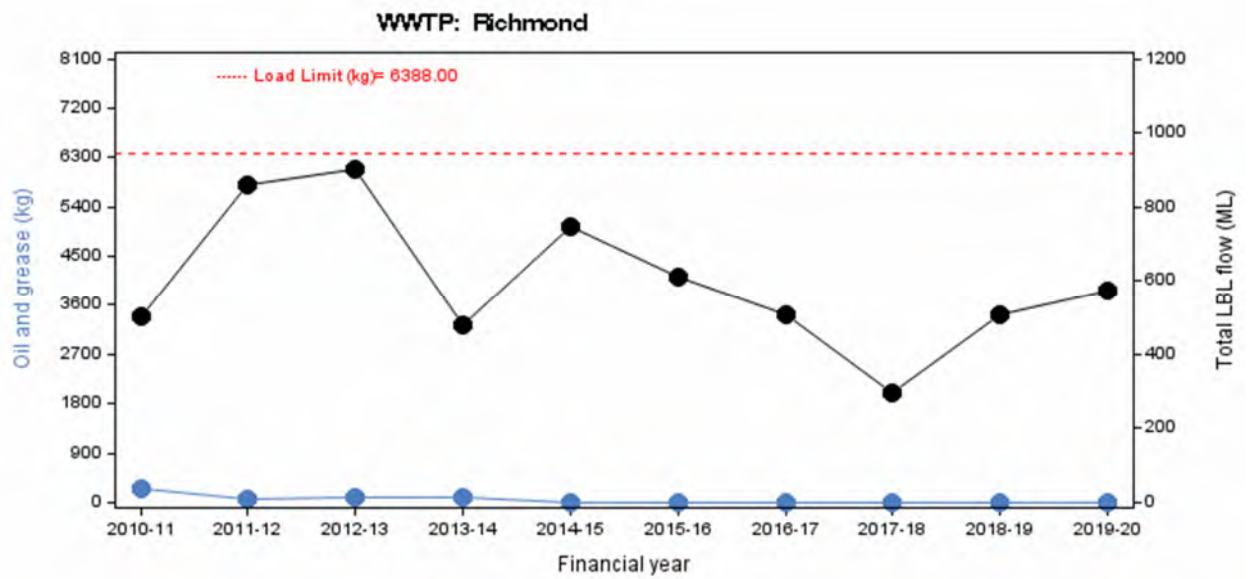


Discharge load: Nutrients



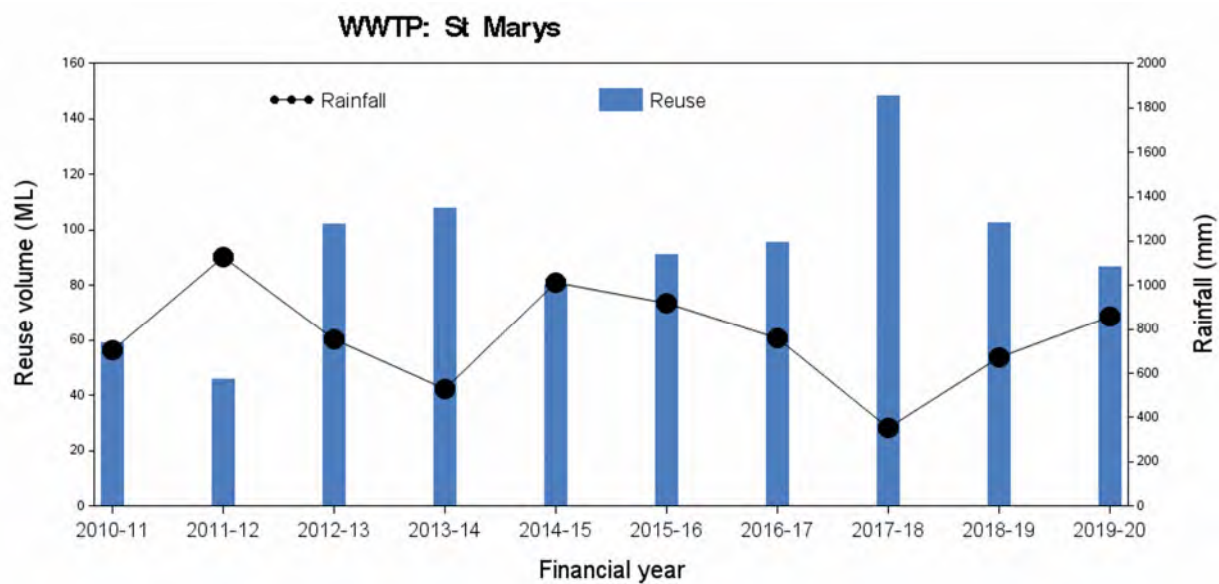
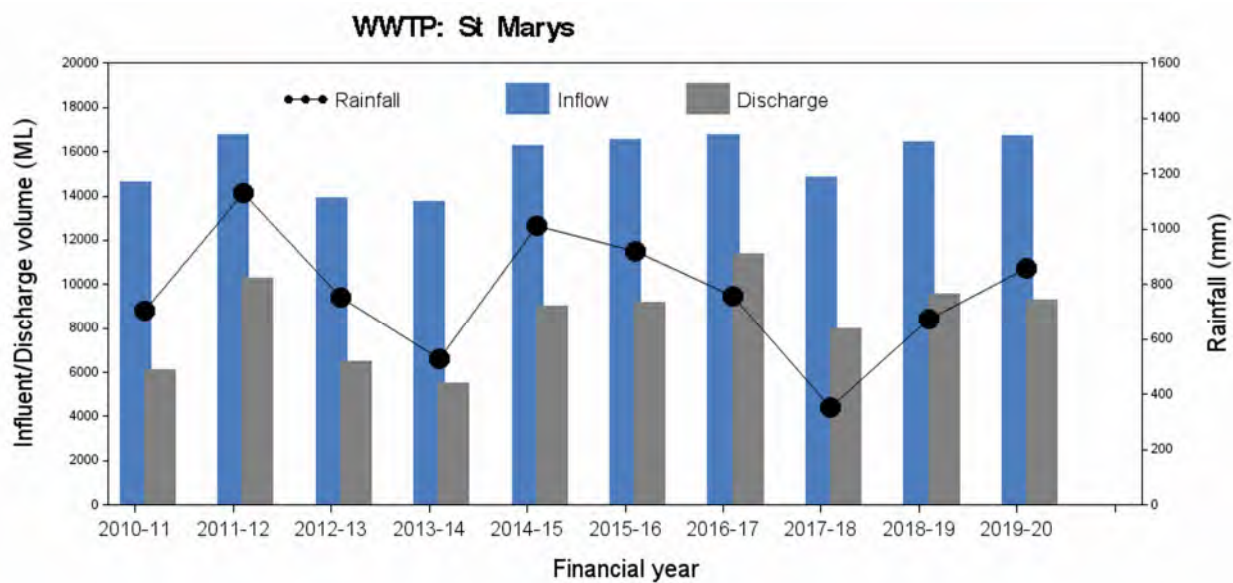
Discharge load: Major conventional analytes

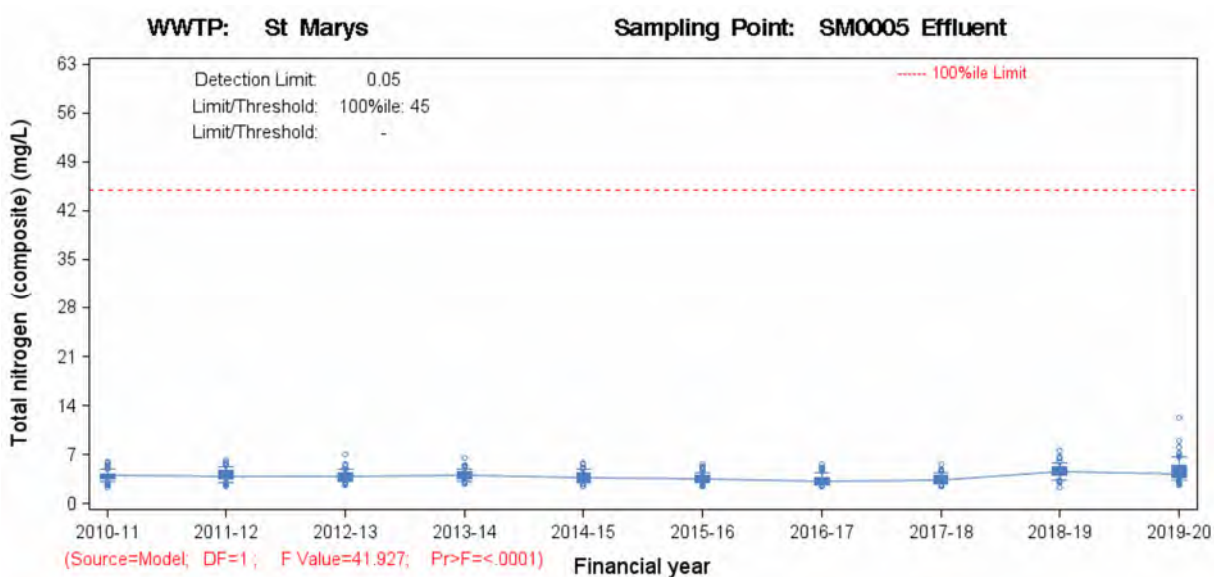
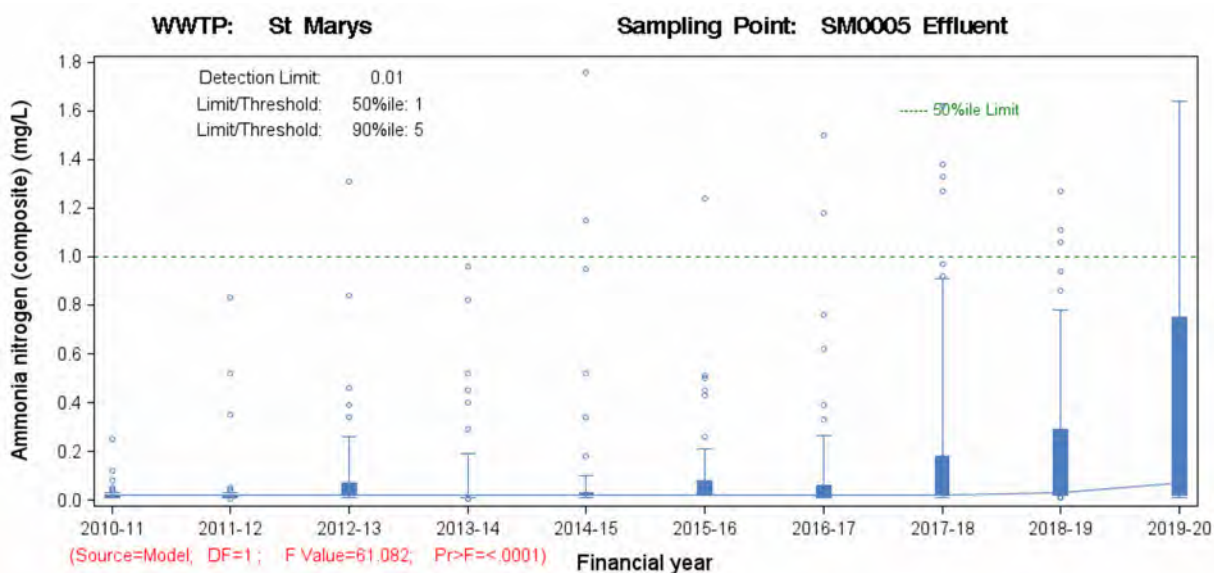
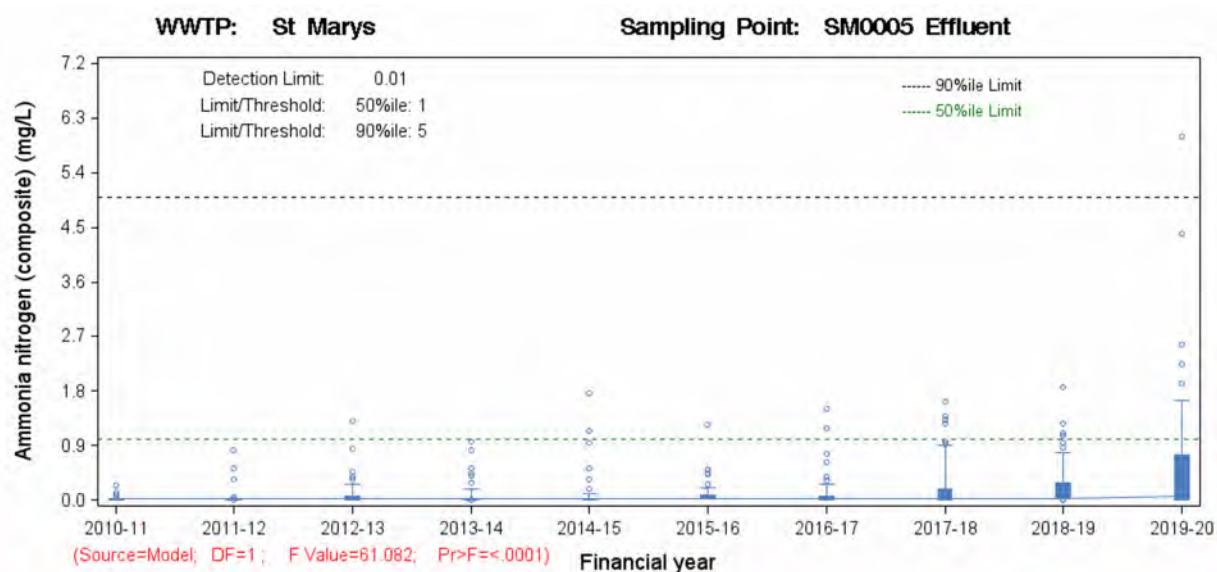


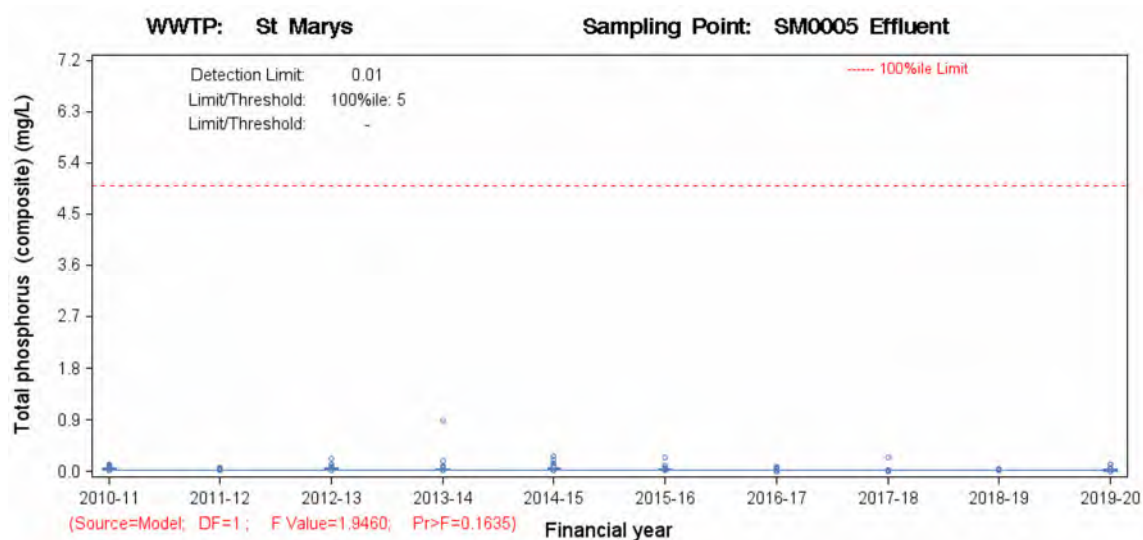
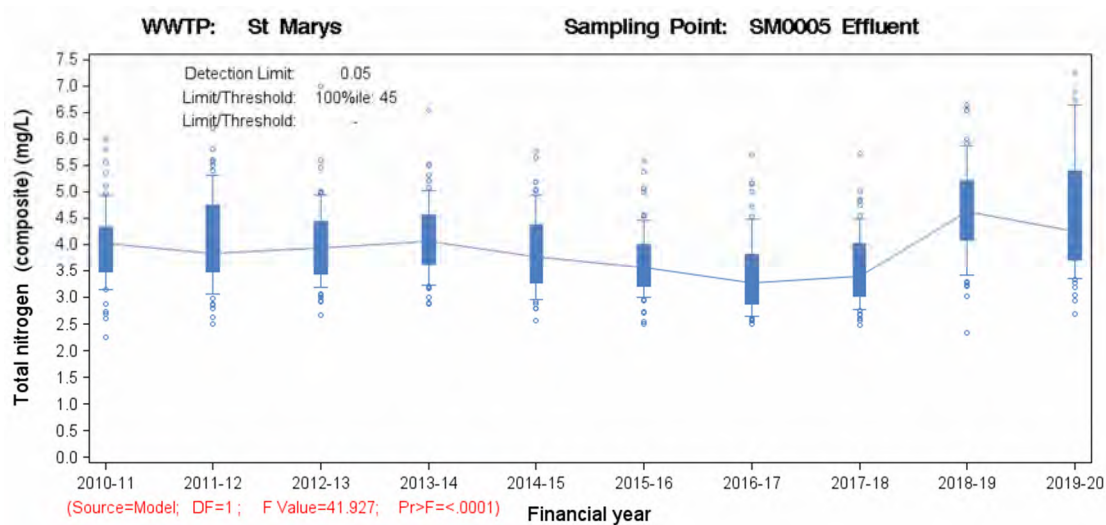


St Marys WWTP

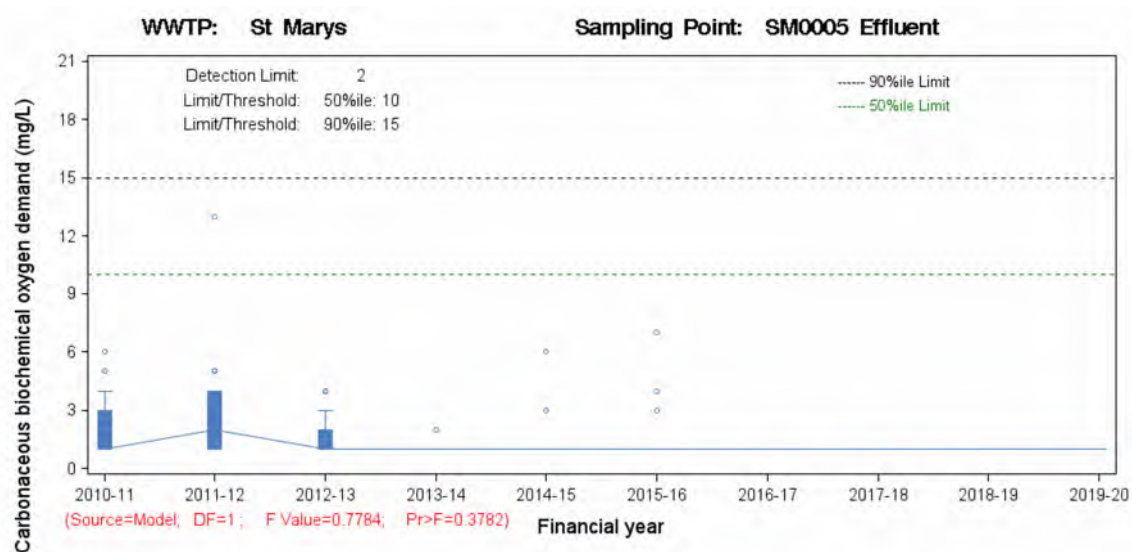
Discharge volume and rainfall



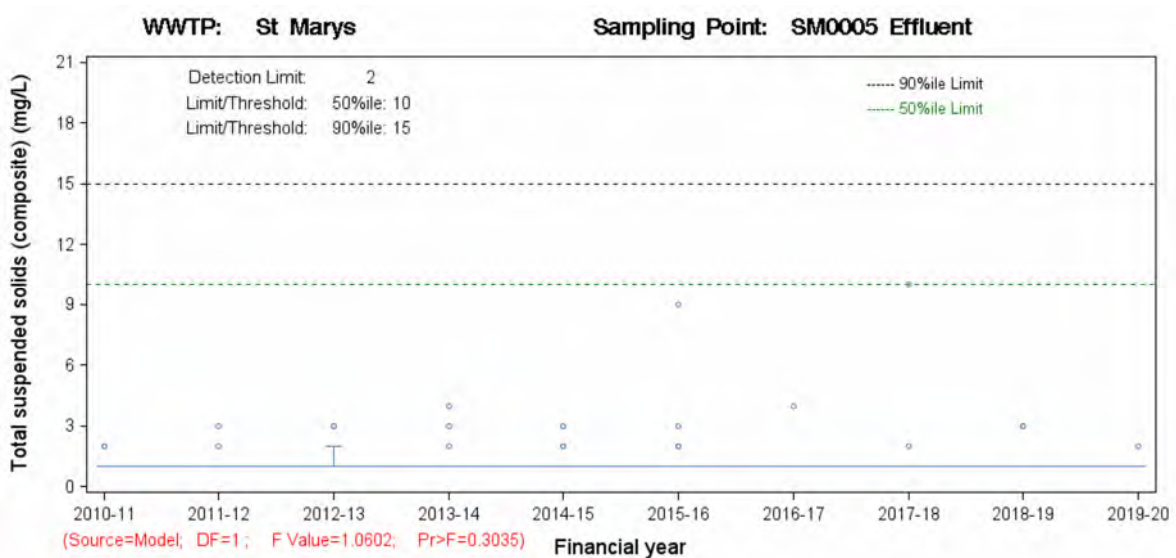
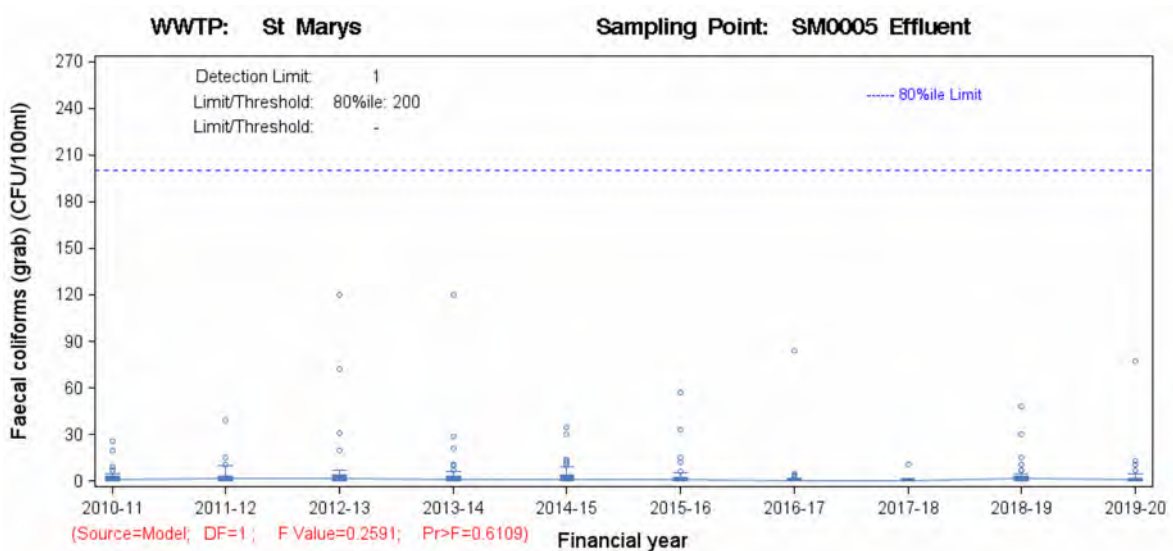
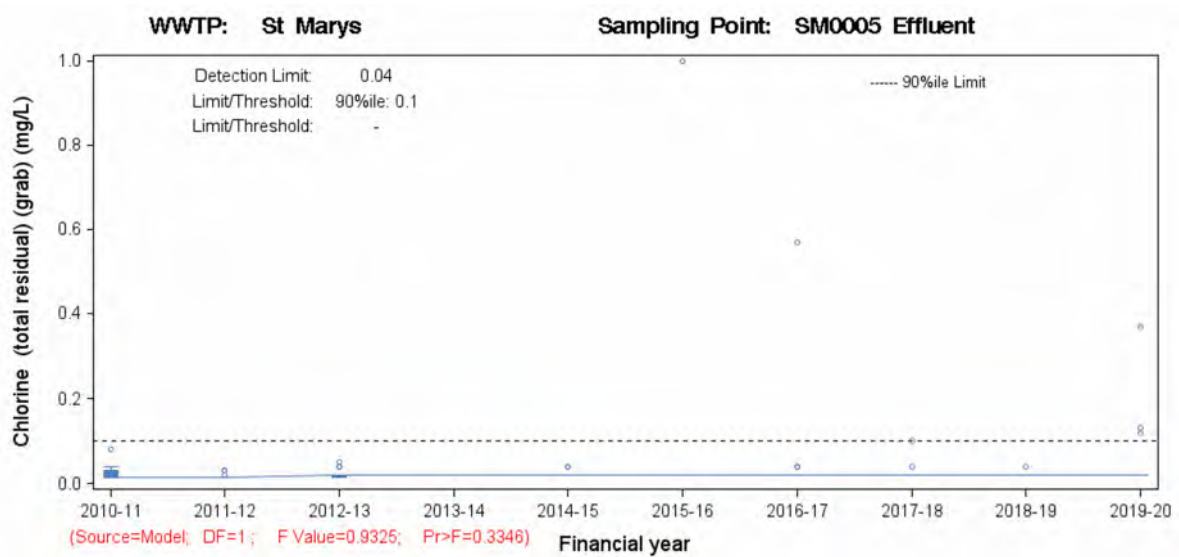




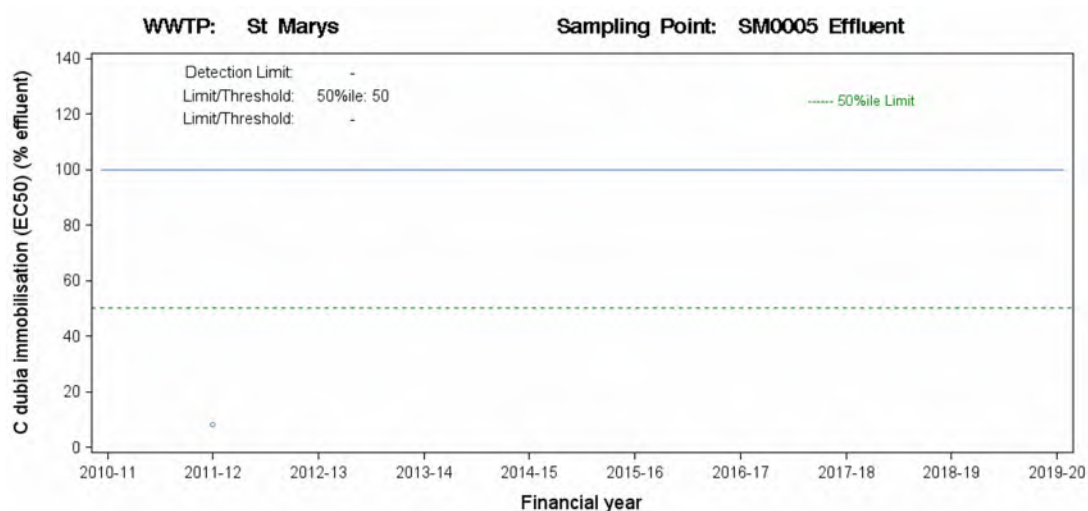
Discharge quality: Major conventional analytes



Note:.. 2019-20 data was compared with previous five years data (2014-2019) due to lab method change in 2014-15.

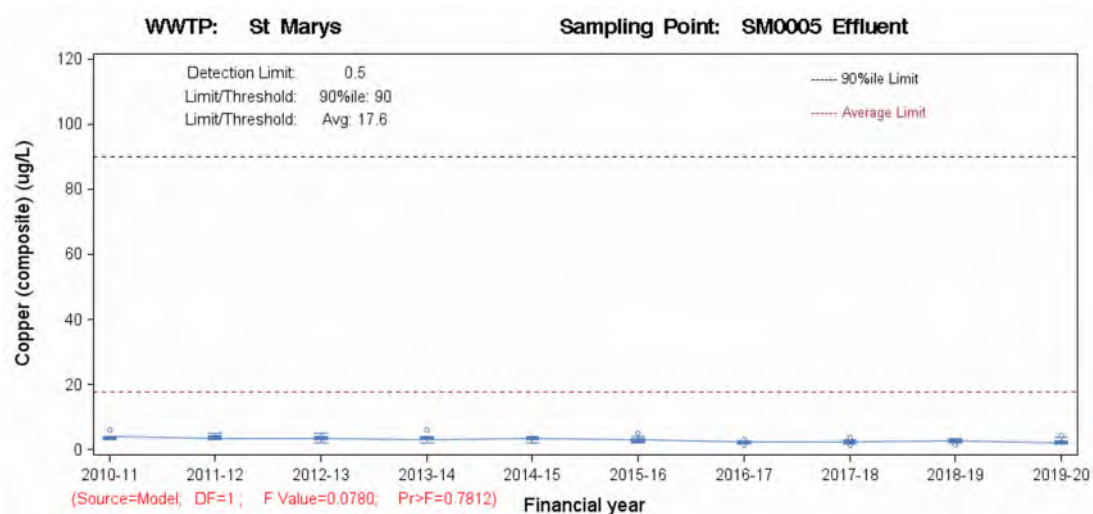
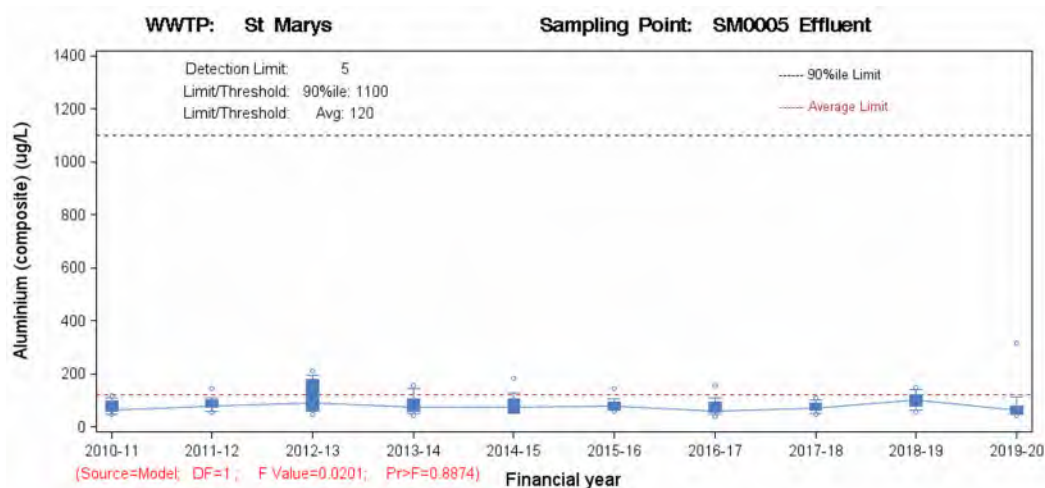


Discharge quality: Toxicity

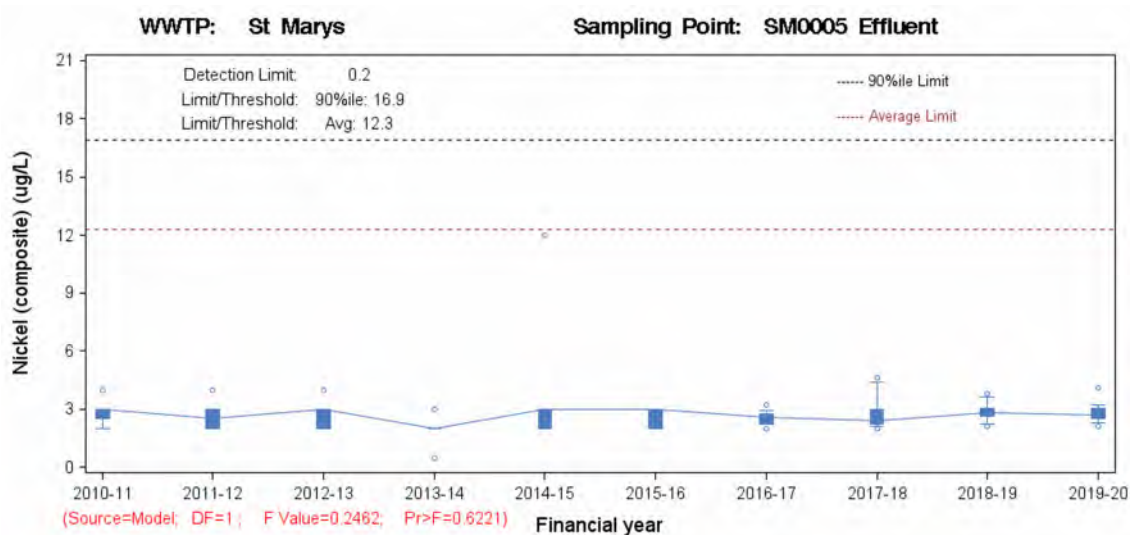
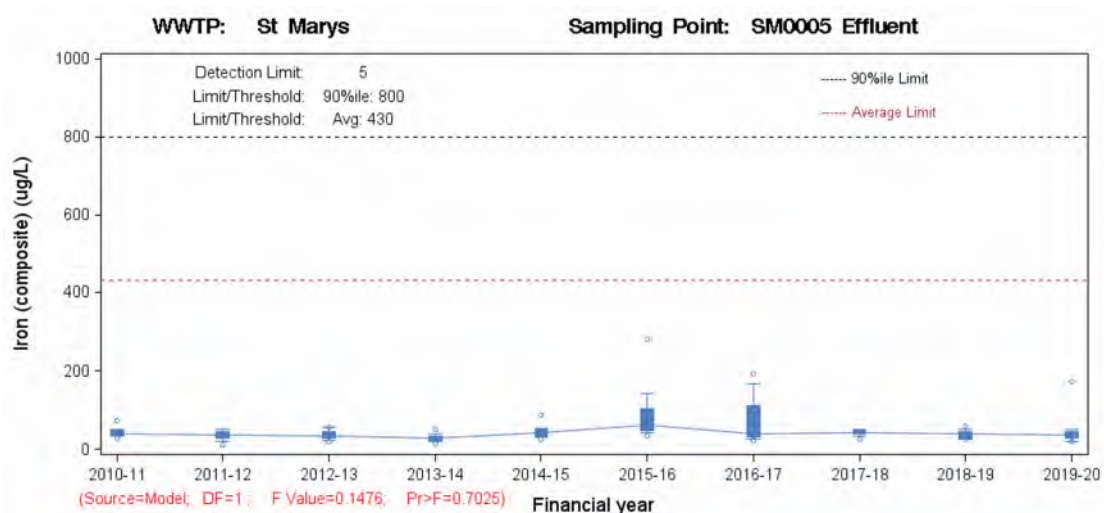


Note: Statistical test was not conducted because >90% of results were recorded at 100% survival for *Ceriodaphnia dubia*.

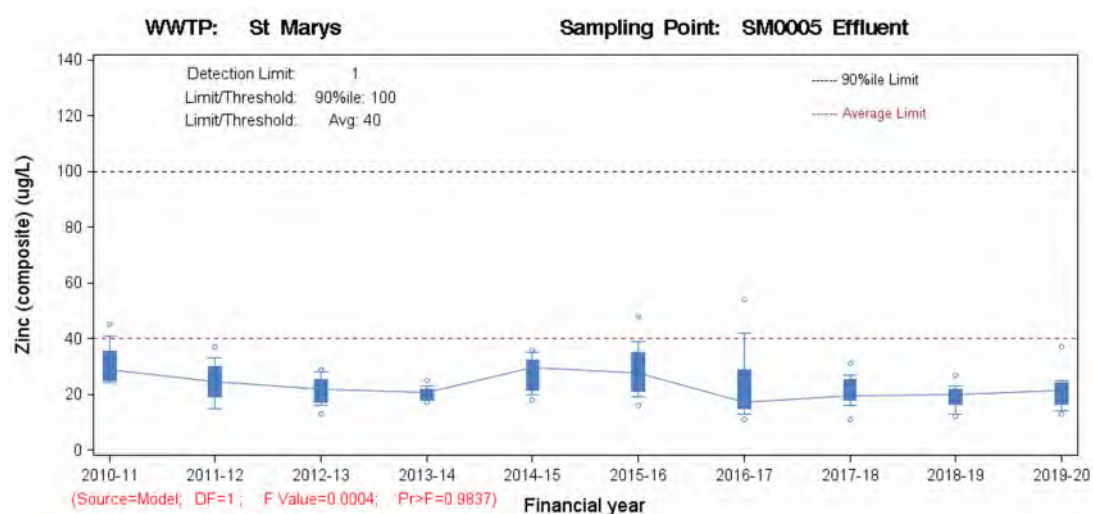
Discharge quality: Trace metals



Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

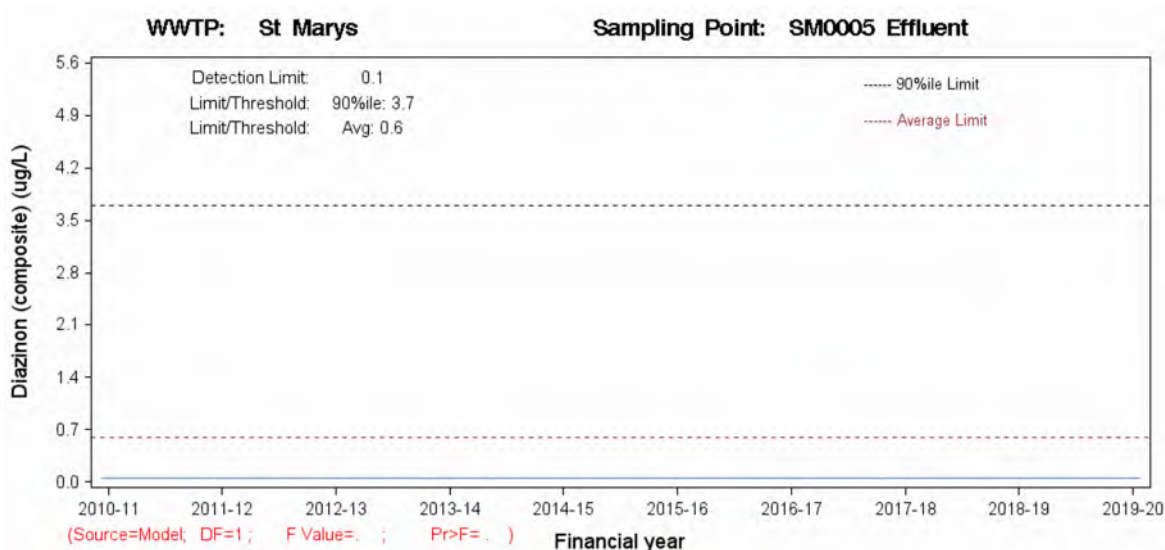


Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

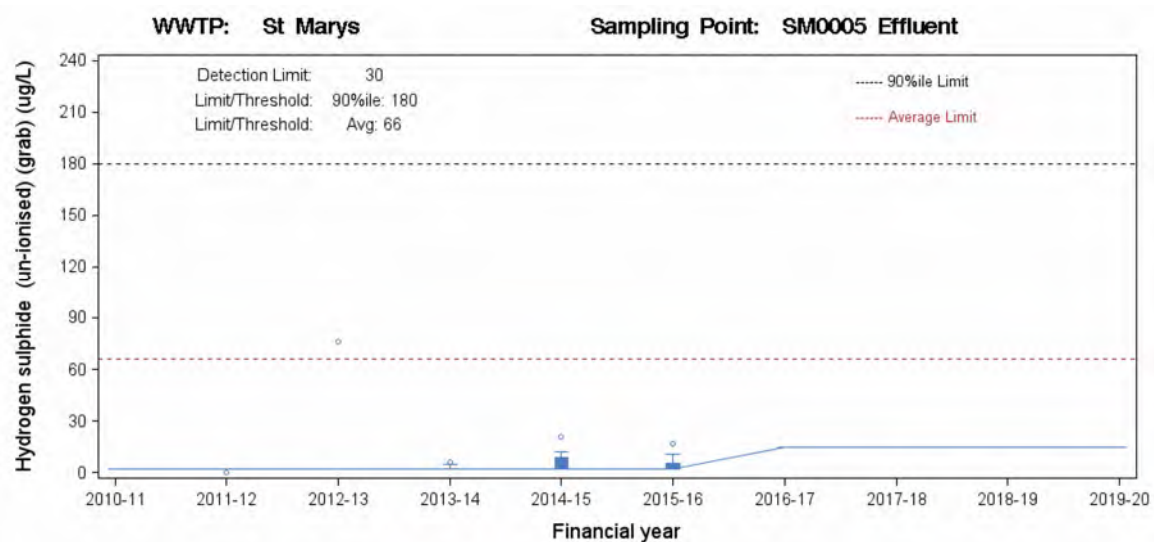


Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

Discharge quality: Other chemicals and organics (including pesticides)

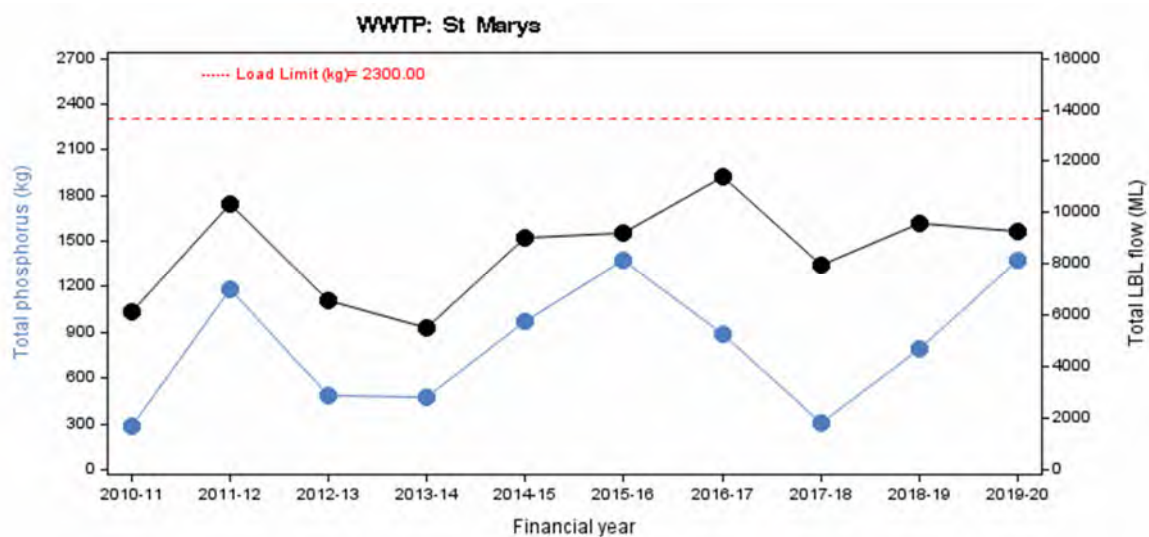
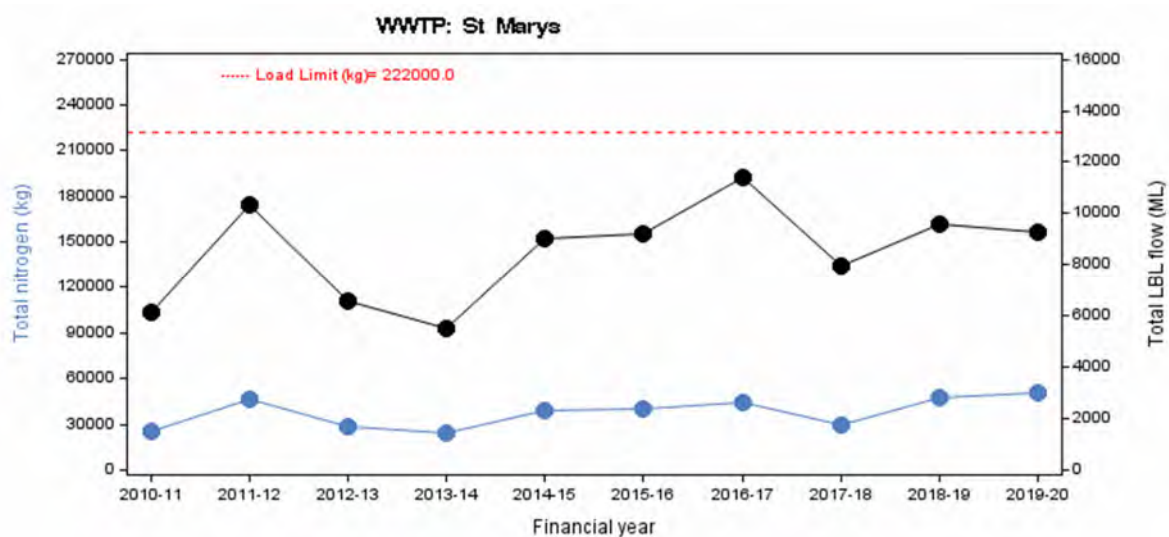


Note: Statistical test was not conducted because >90% of results were below the detection limit.

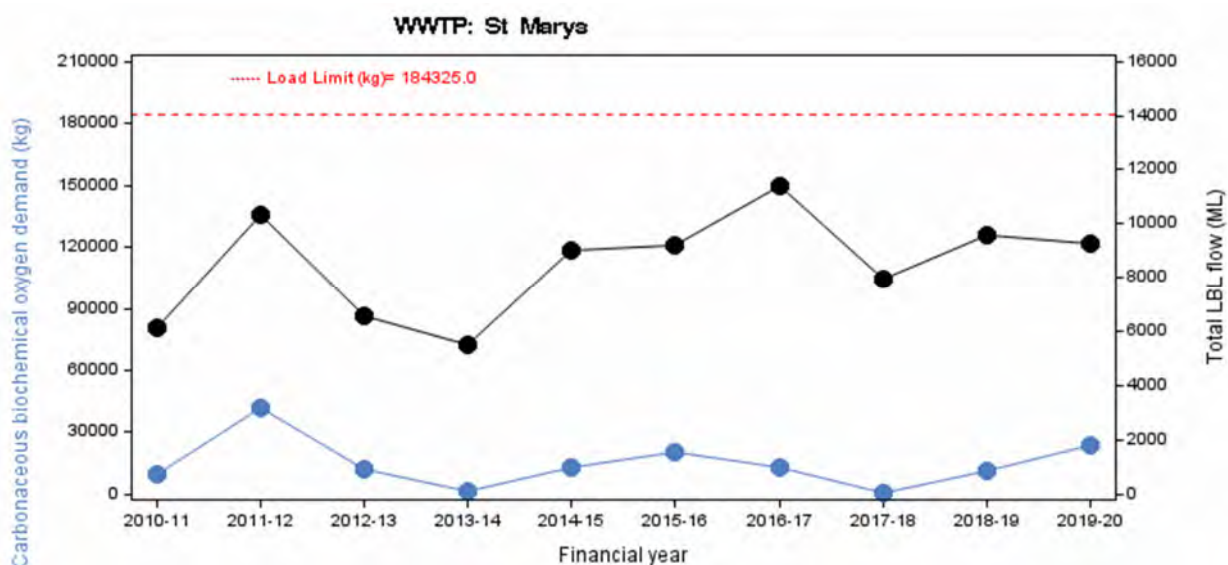


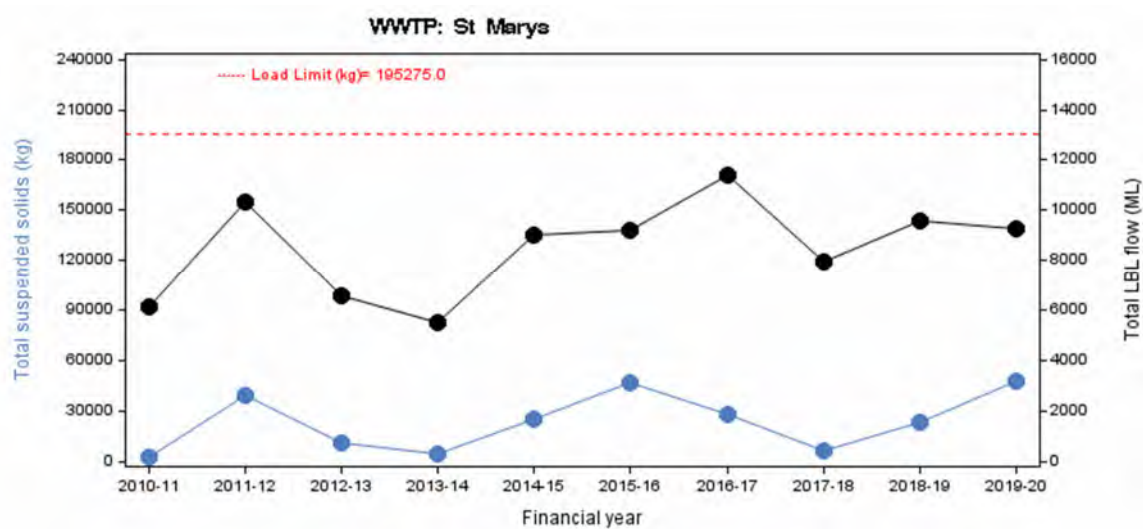
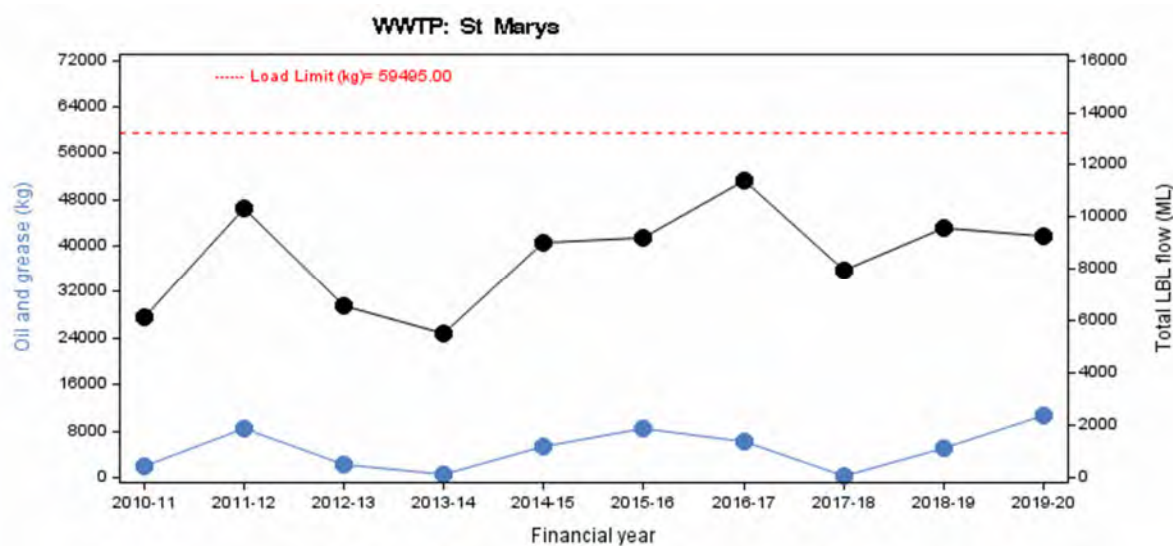
Note: 2019-20 data was compared with previous three years data (2016-2019) due to lab method change in 2016-17.
Statistical test was not conducted because >90% of results were below the detection limit.

Discharge load: Nutrients

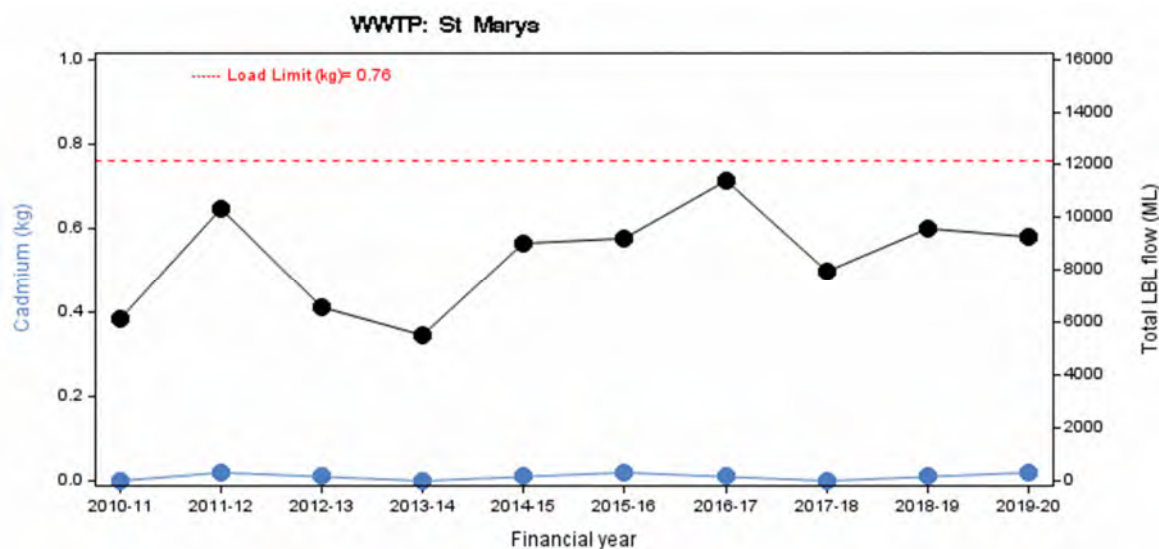


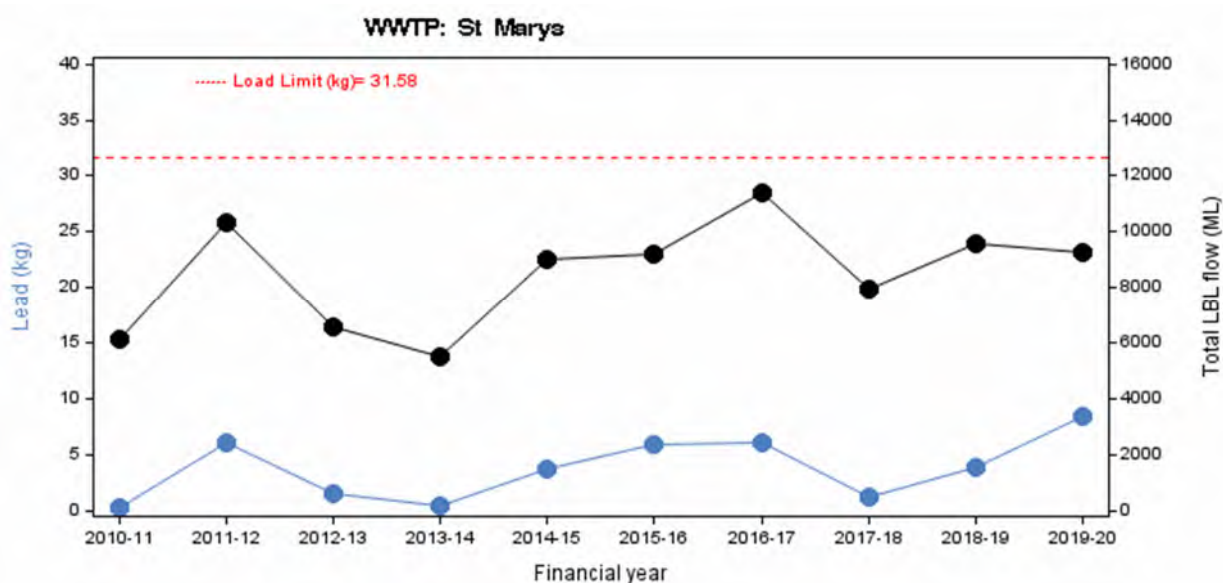
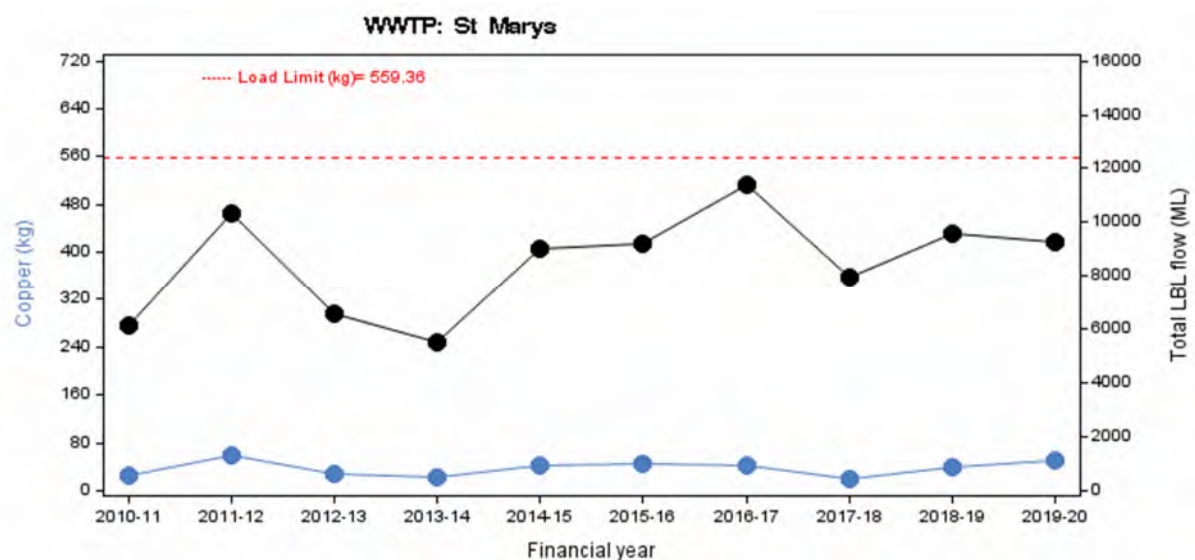
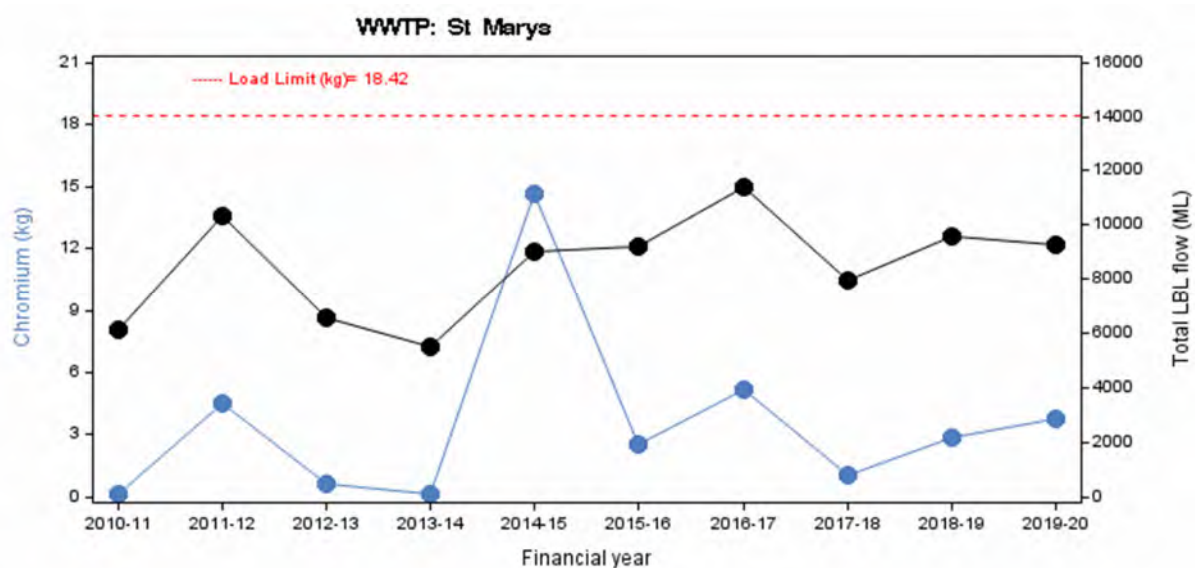
Discharge load: Major conventional analytes

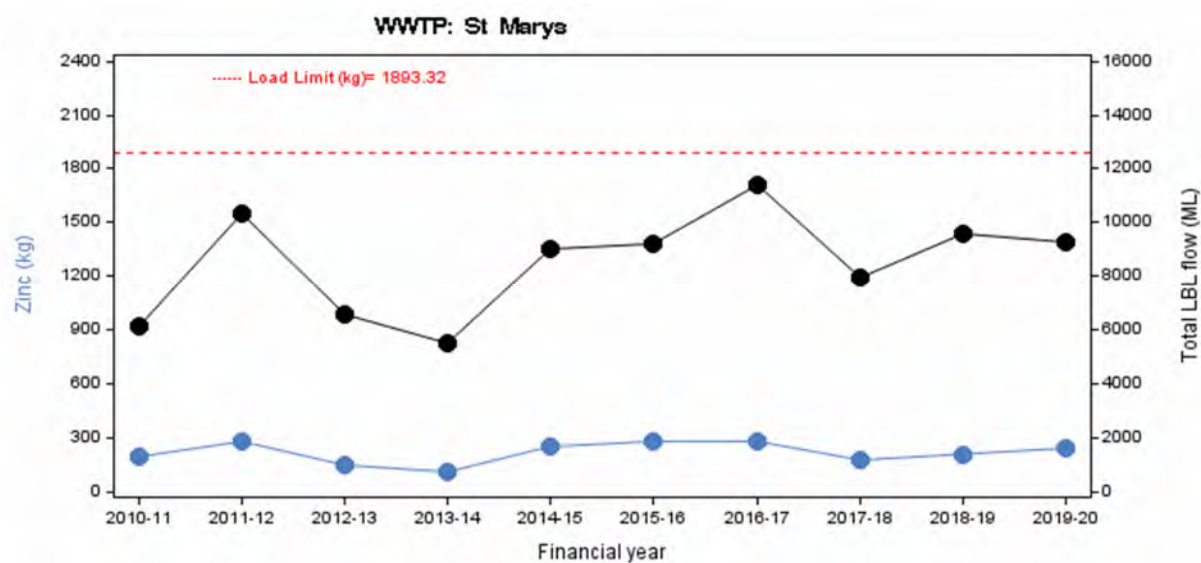
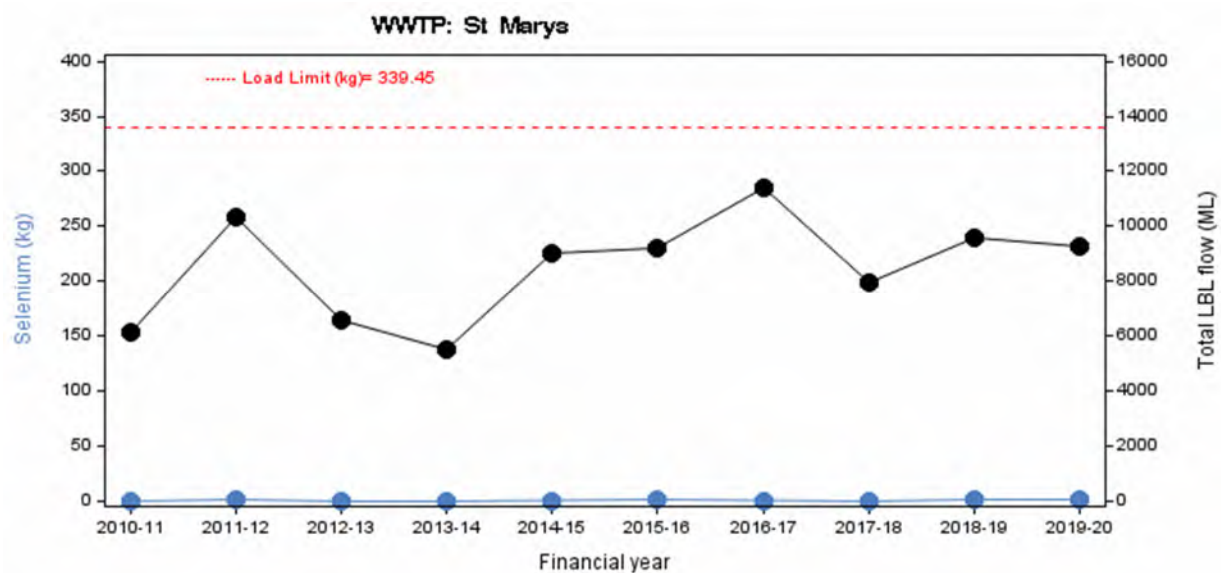
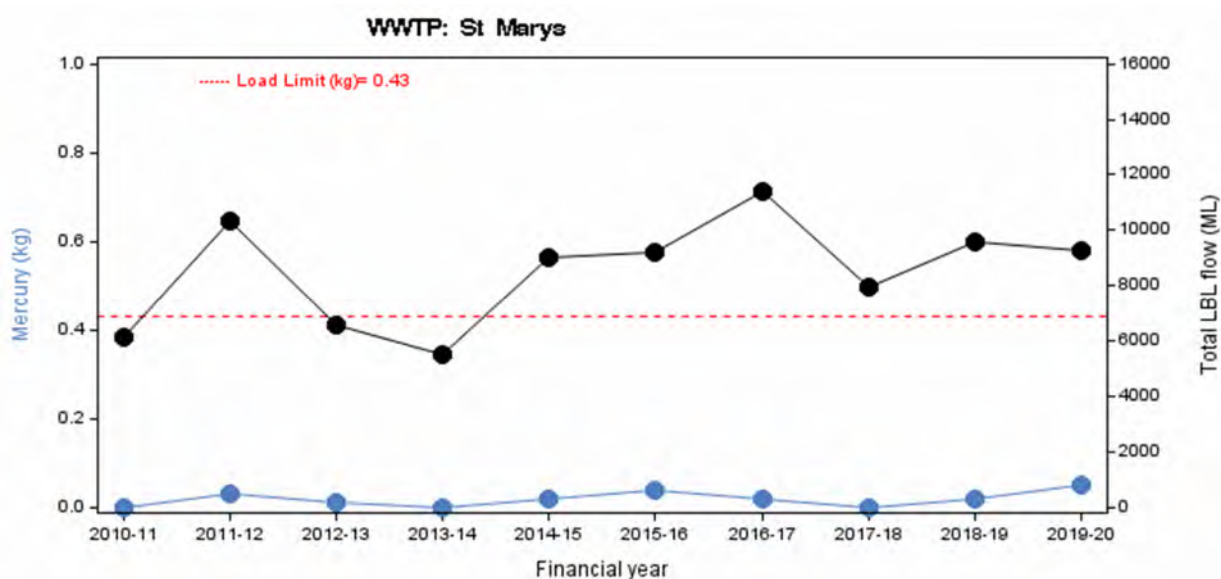




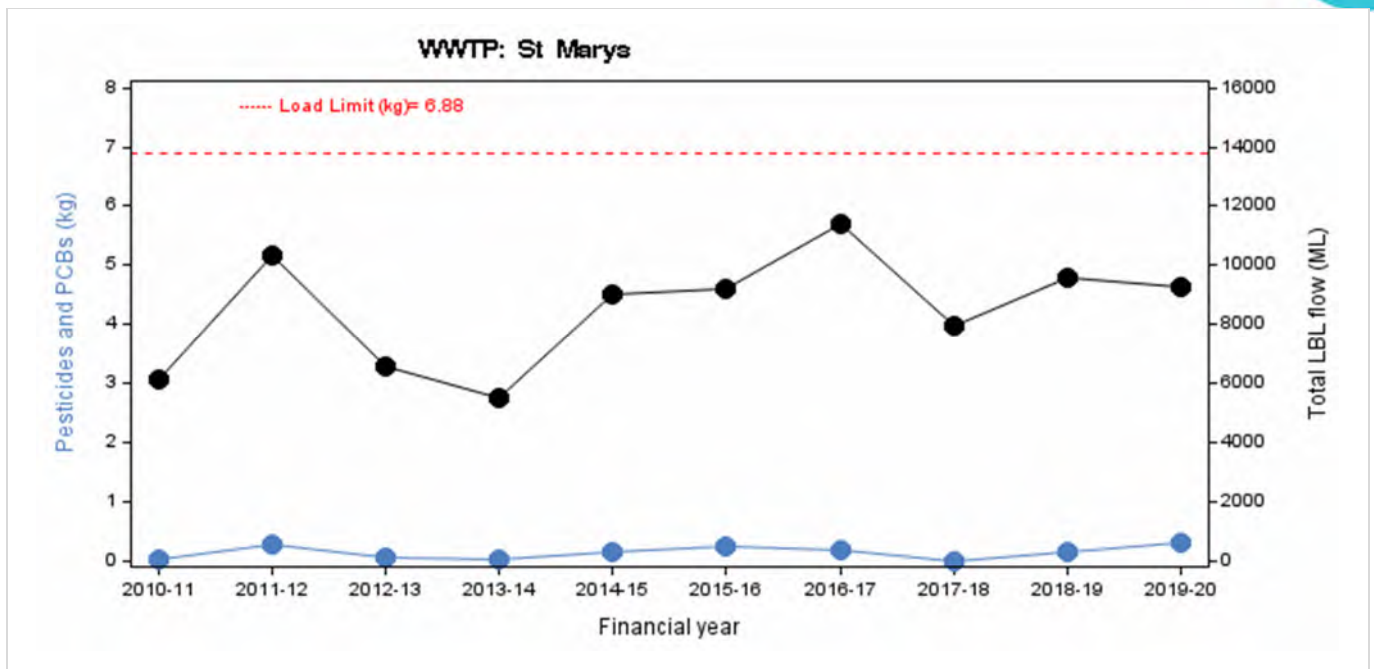
Discharge load: Trace metals





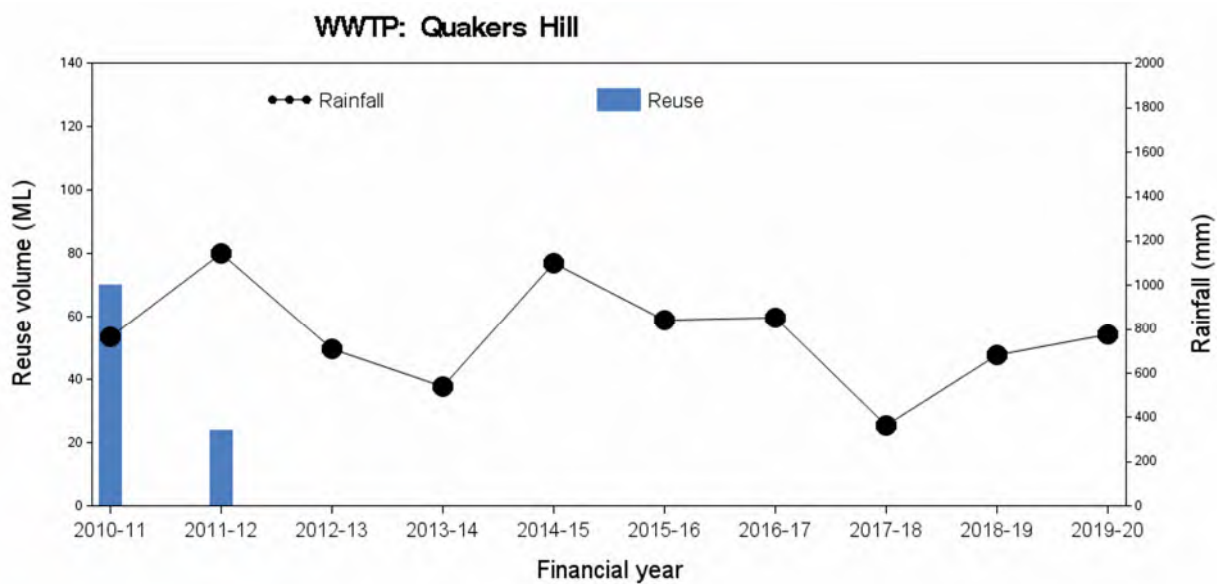
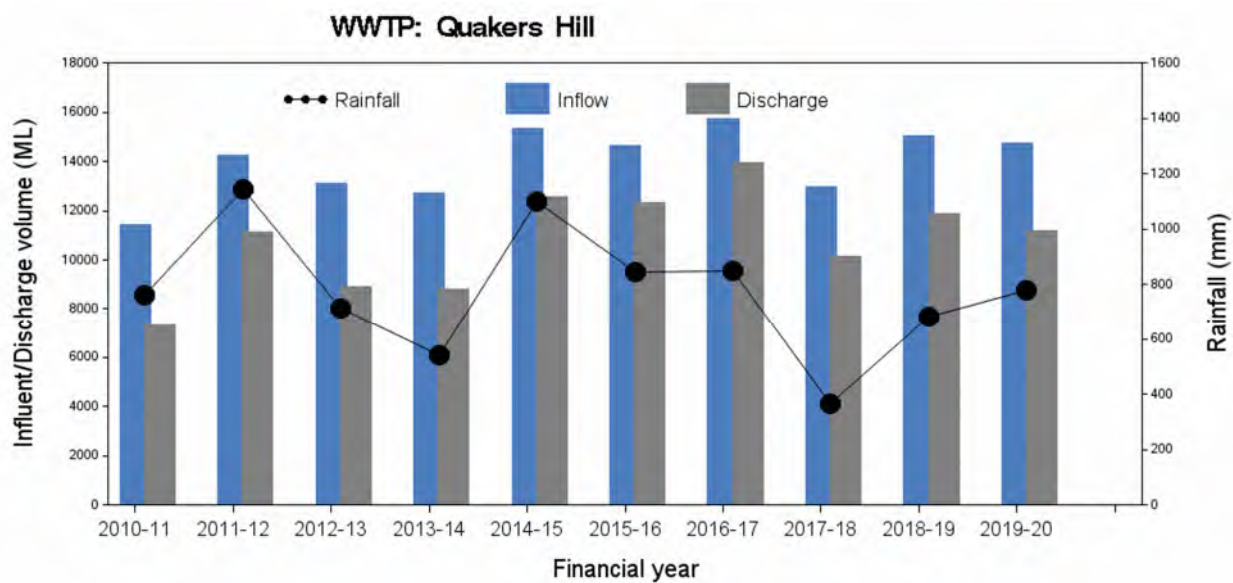


Discharge load: Other chemicals and organics (including pesticides)

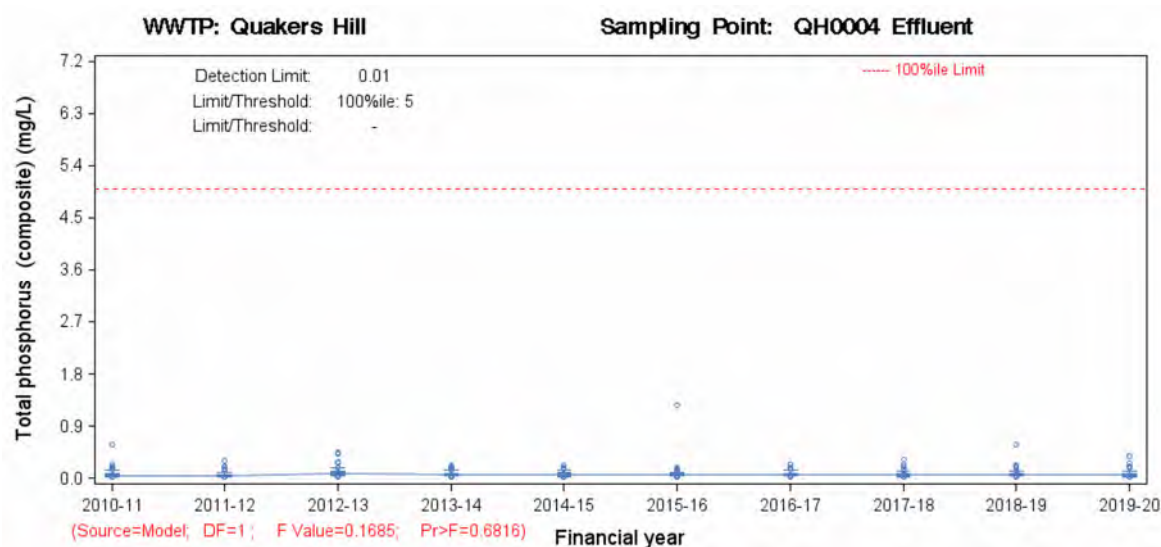
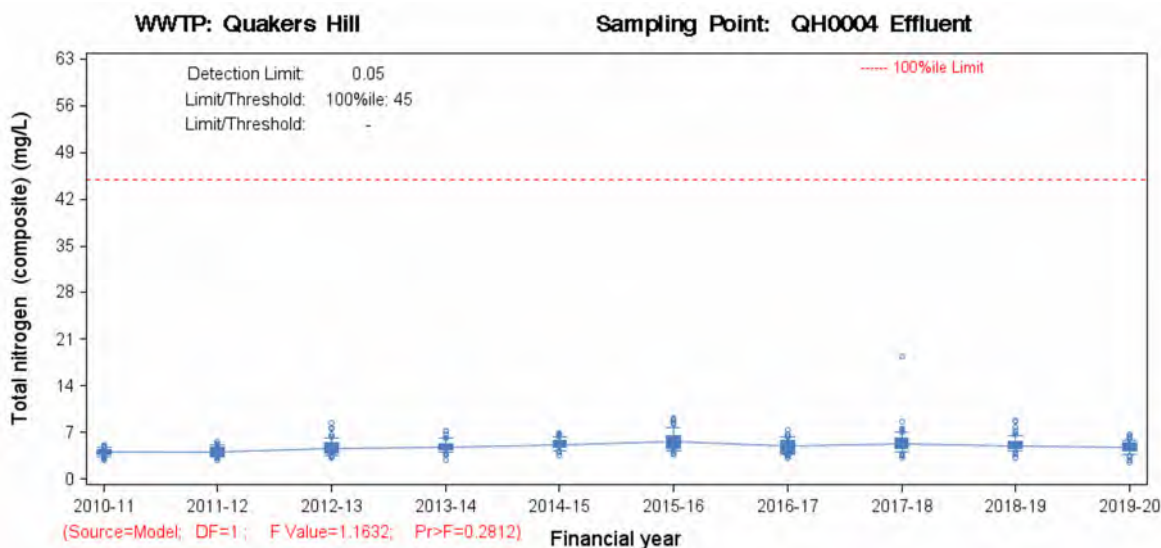
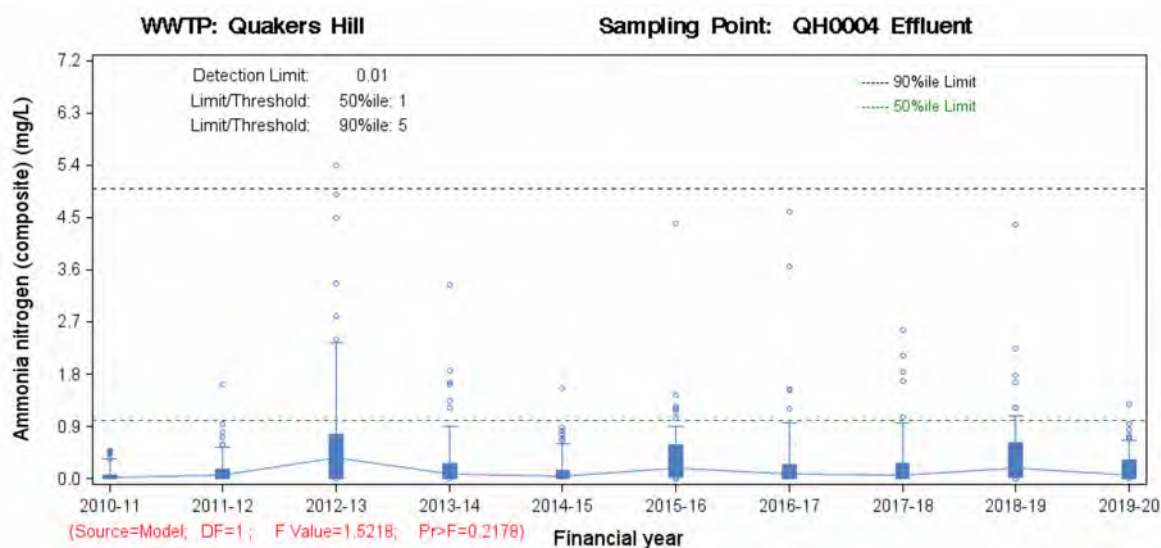


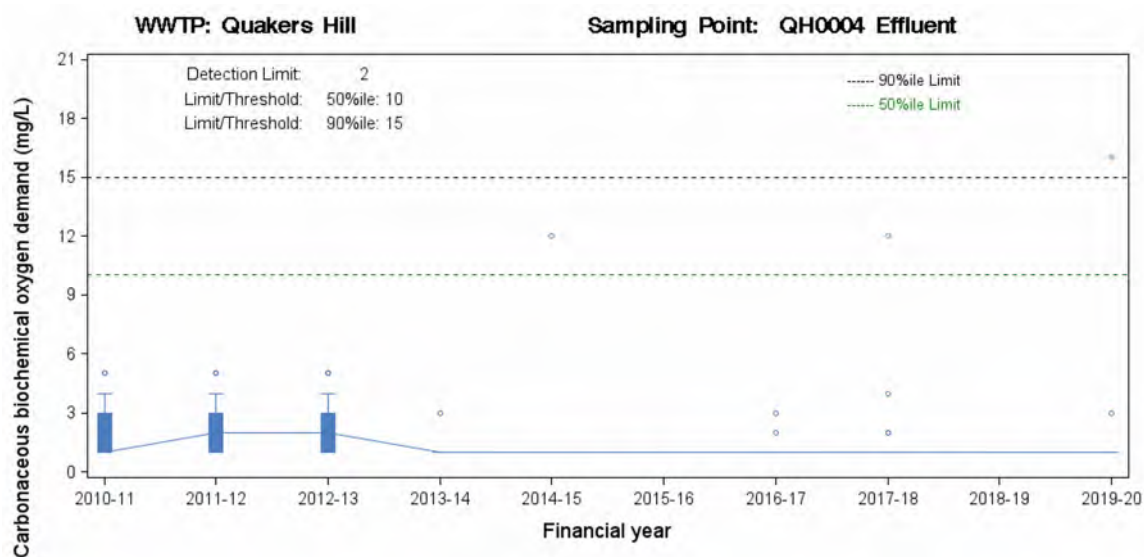
Quakers Hill WWTP

Discharge volume and rainfall

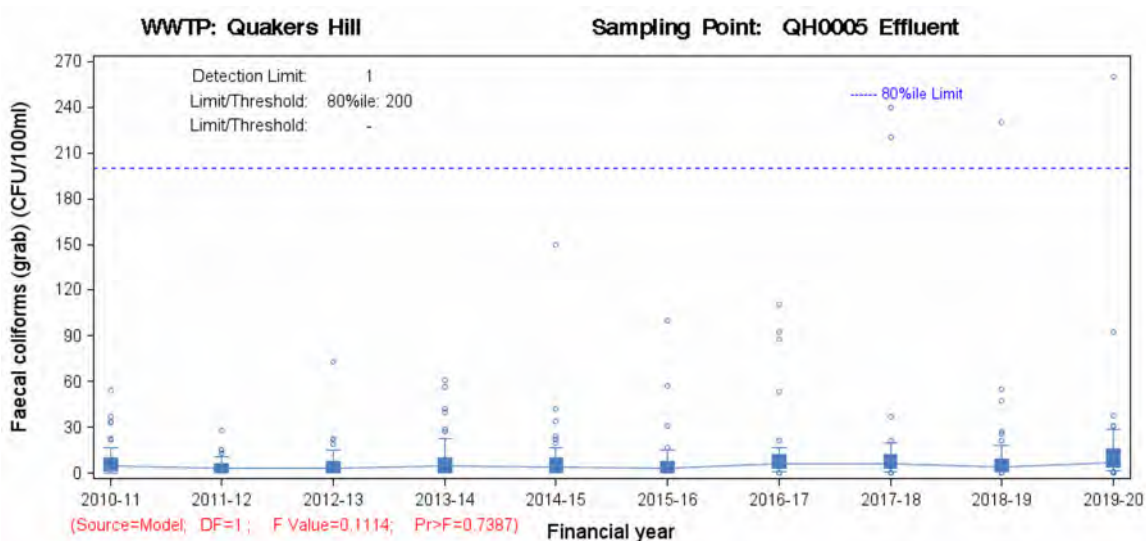
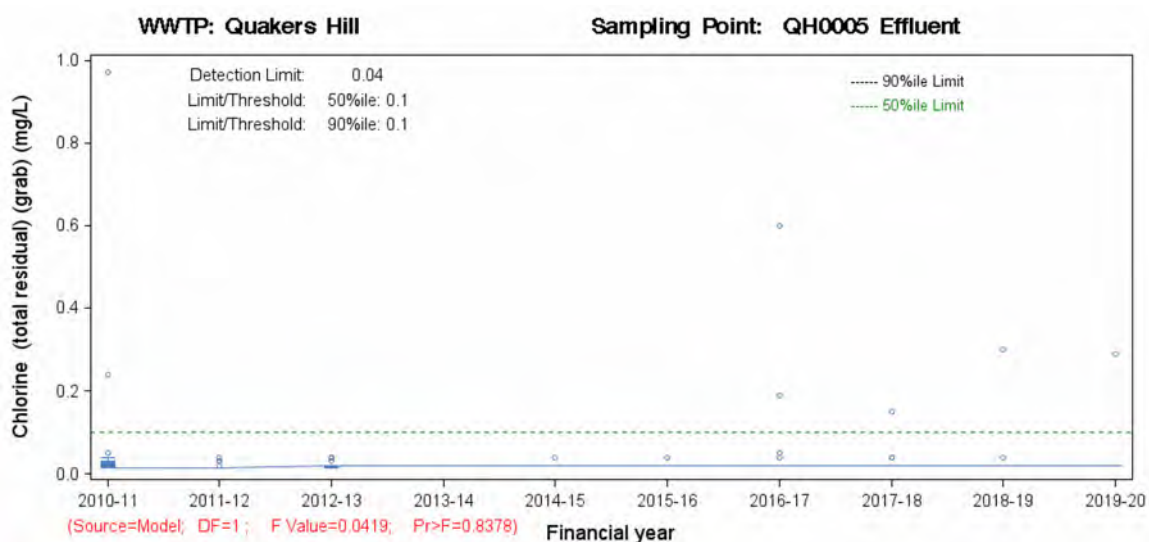


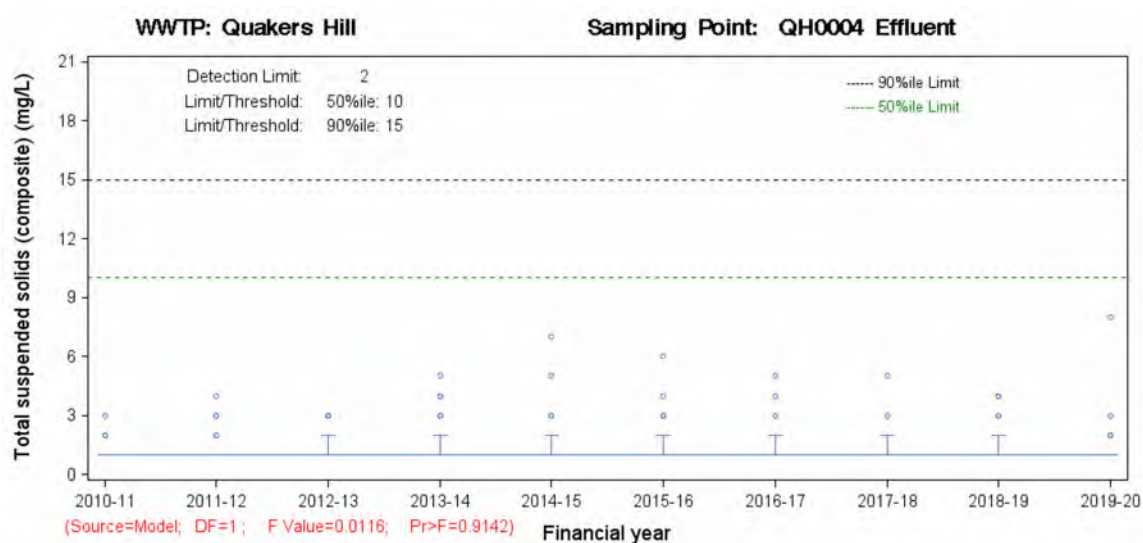
Discharge quality: Nutrients



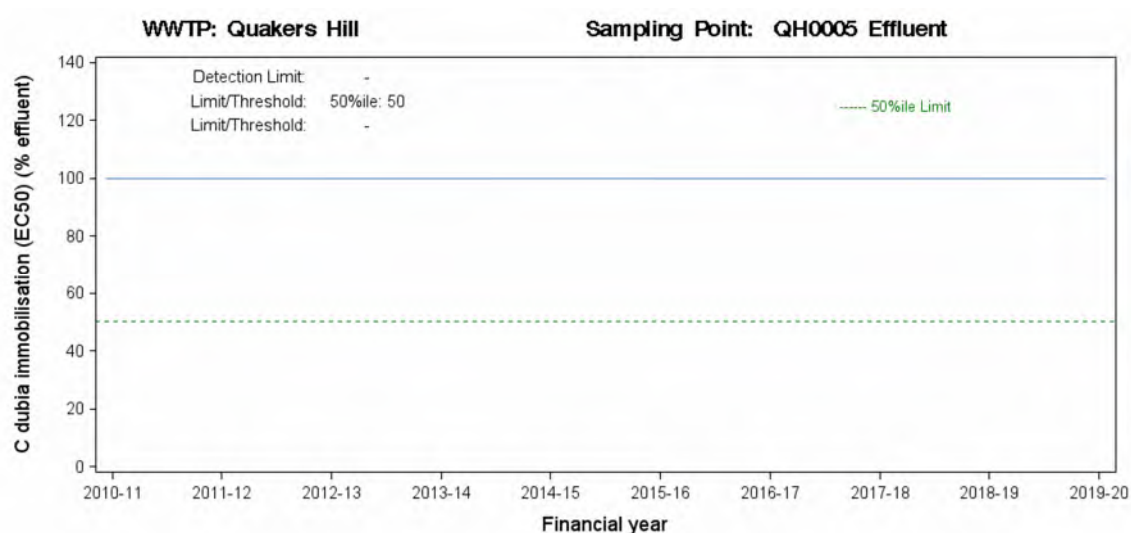


Note: 2019-20 data was compared with previous five years data (2014-2019) due to lab method change in 2014-15. Statistical test was not conducted because >90% of results were below the detection limit.

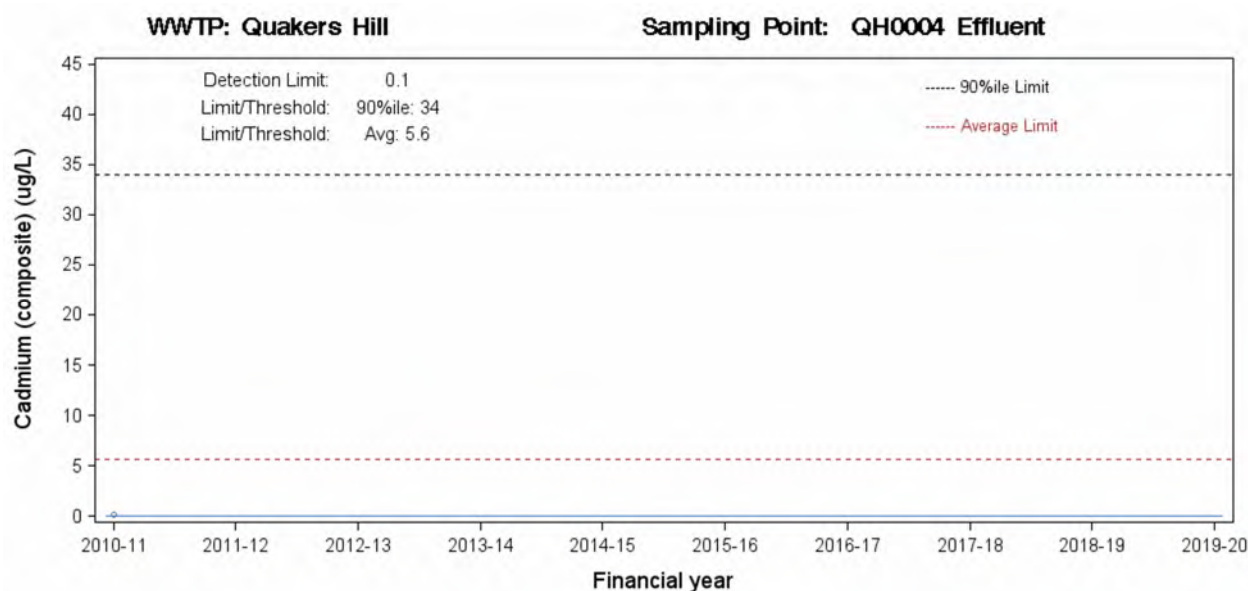
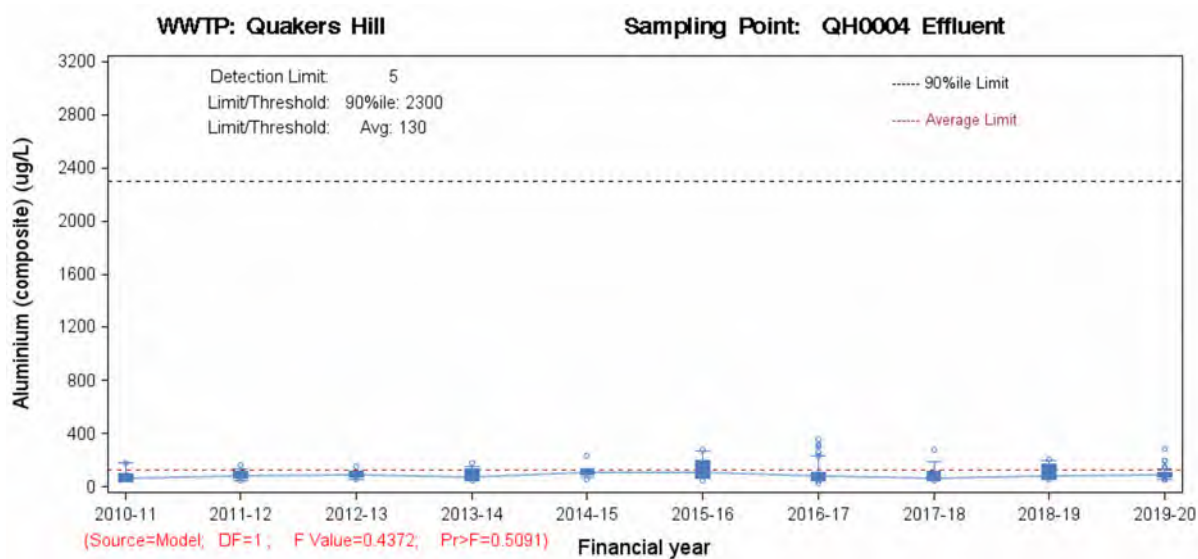




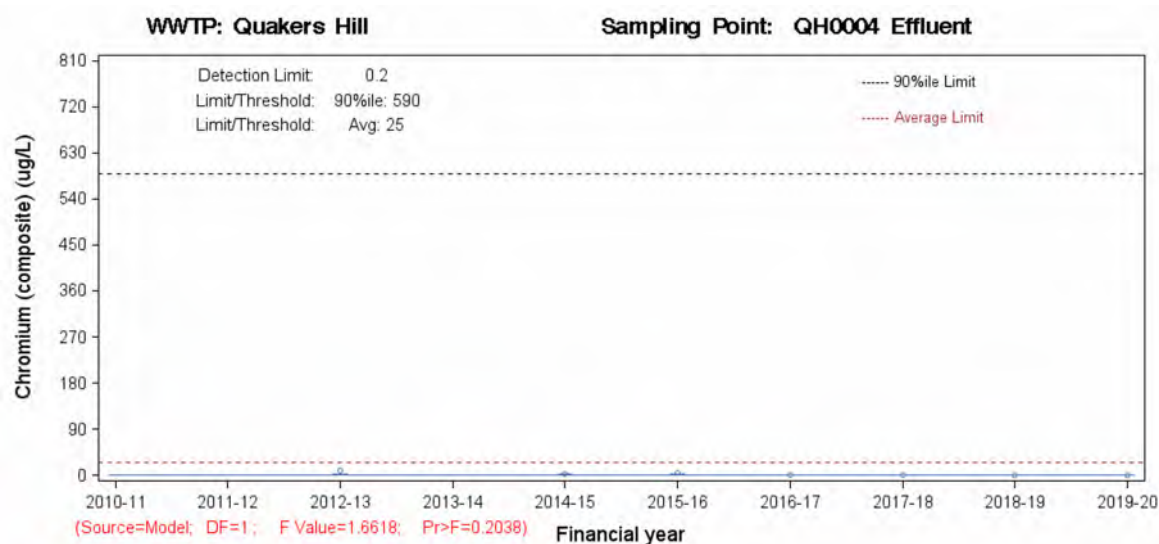
Discharge quality: Toxicity

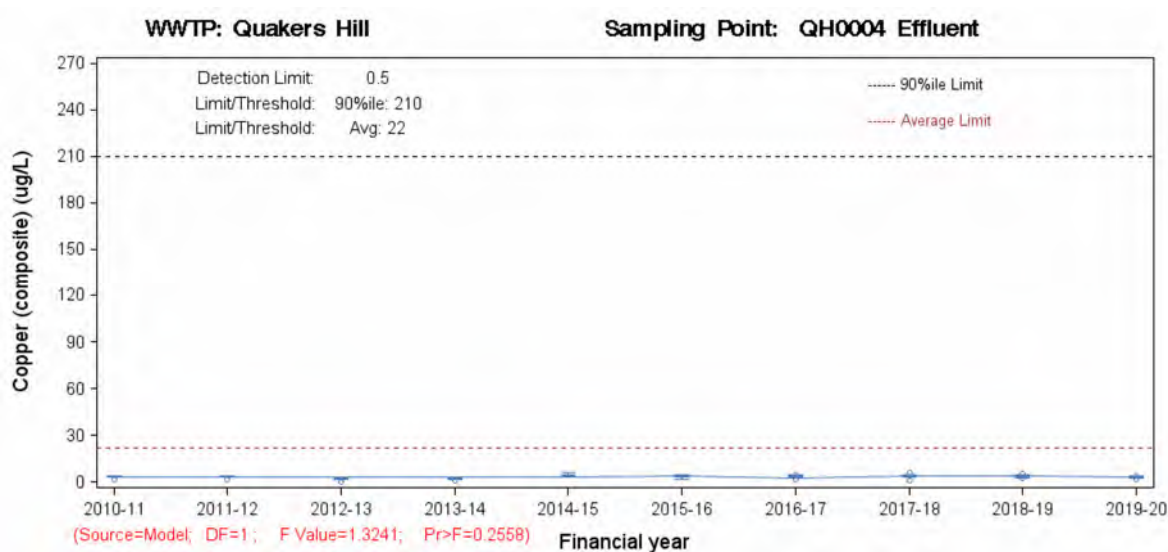
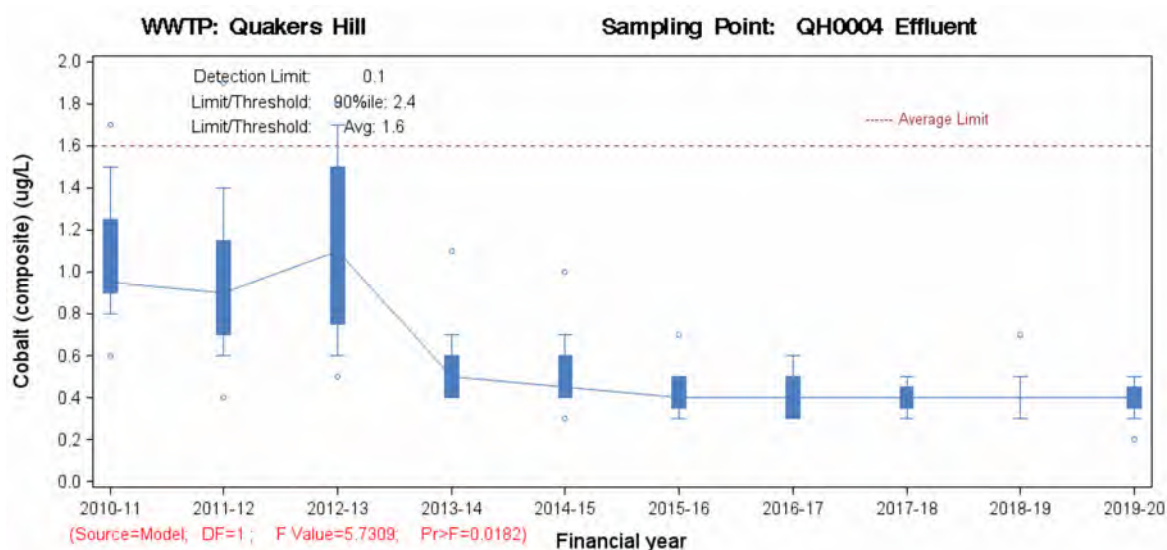
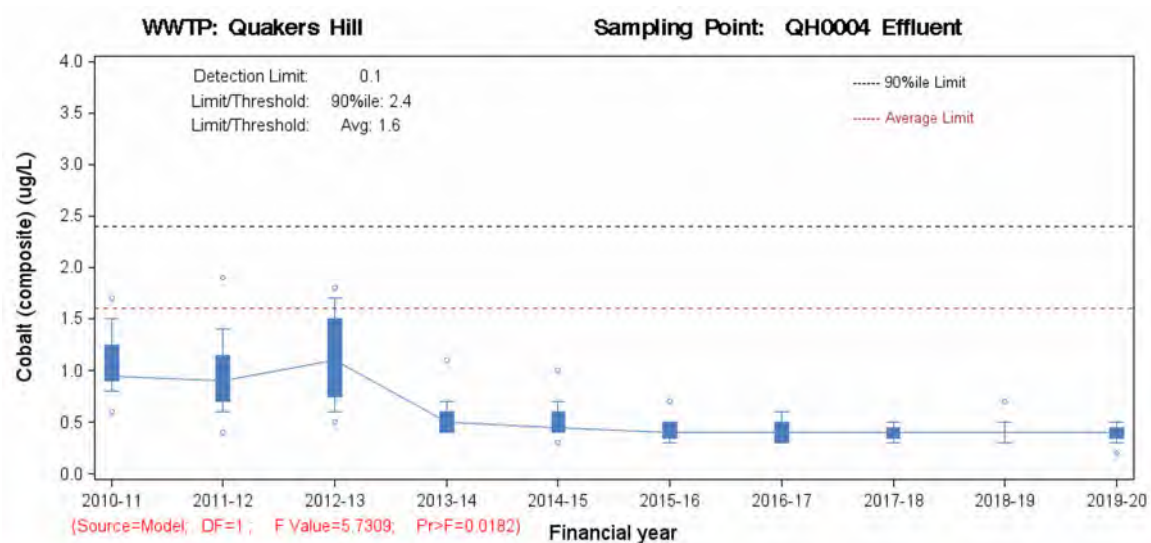


Note: Statistical test was not conducted because >90% of results were recorded at 100% survival for *Ceriodaphnia dubia*.

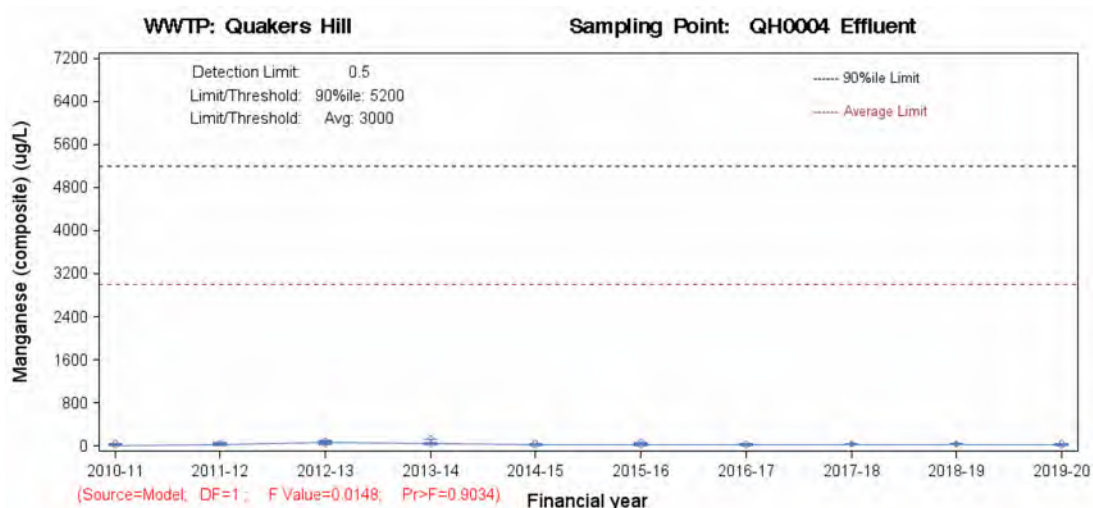


Note: Statistical test was not conducted because >90% of results were below the detection limit.

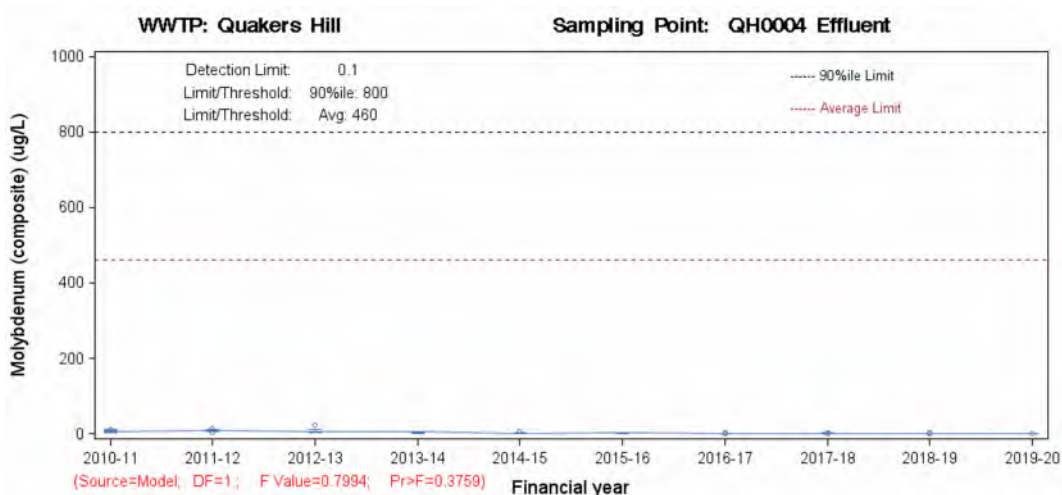




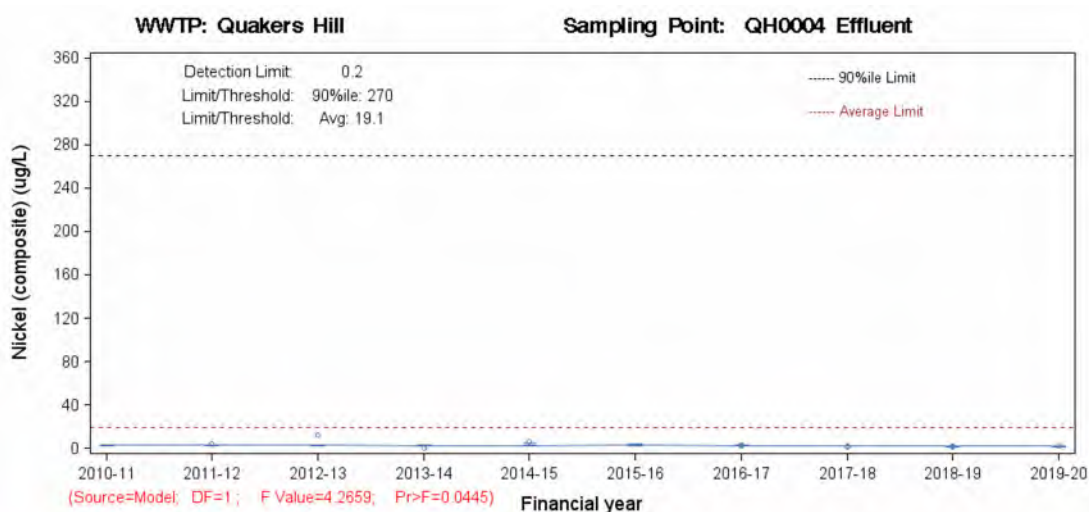
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.



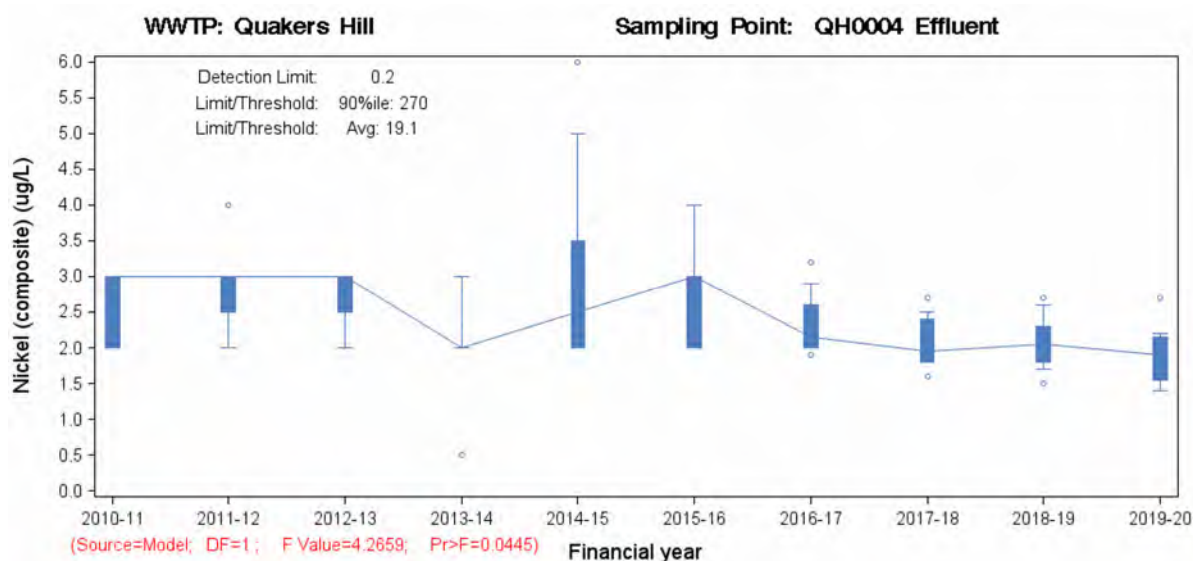
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.



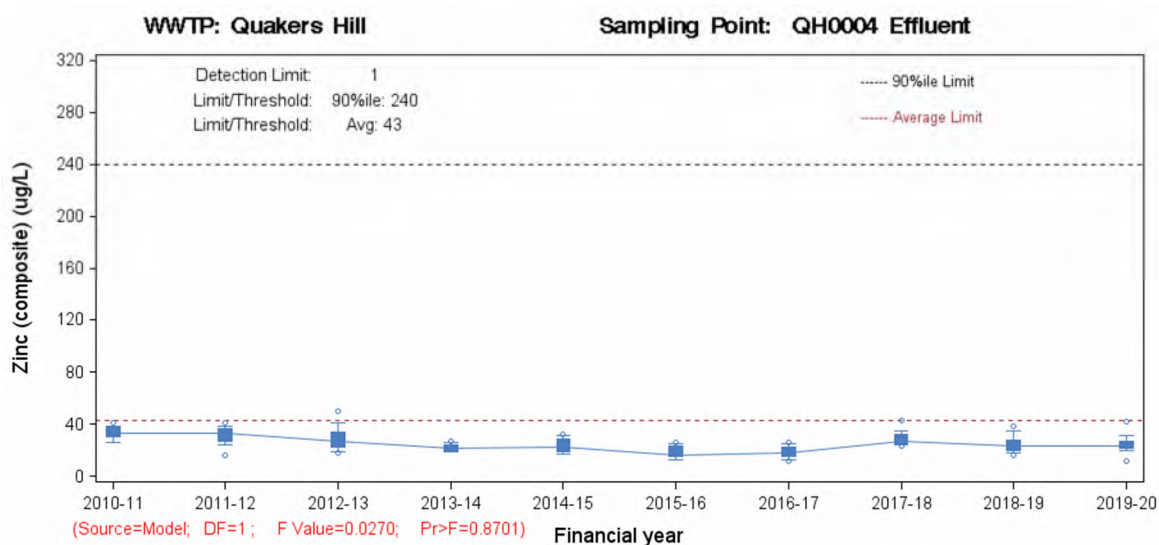
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.



Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

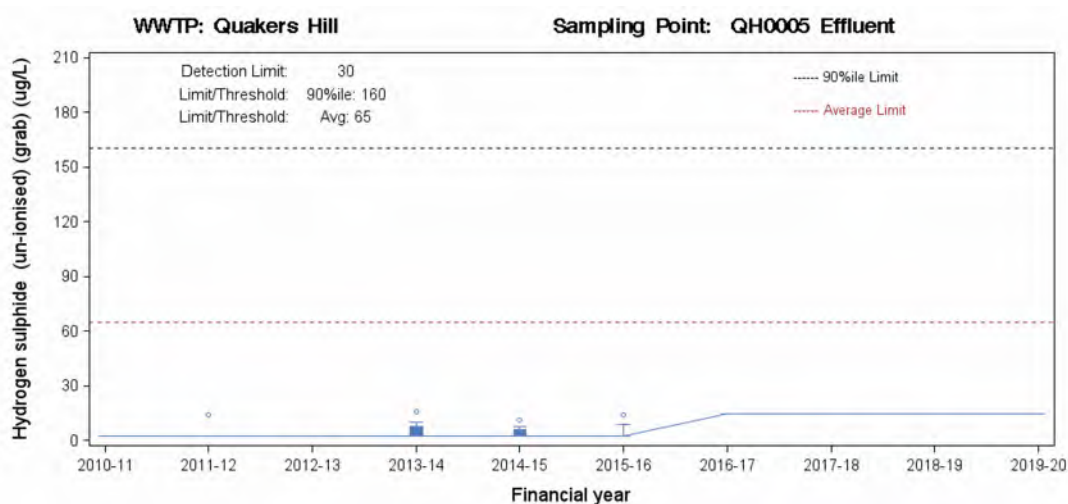


Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.



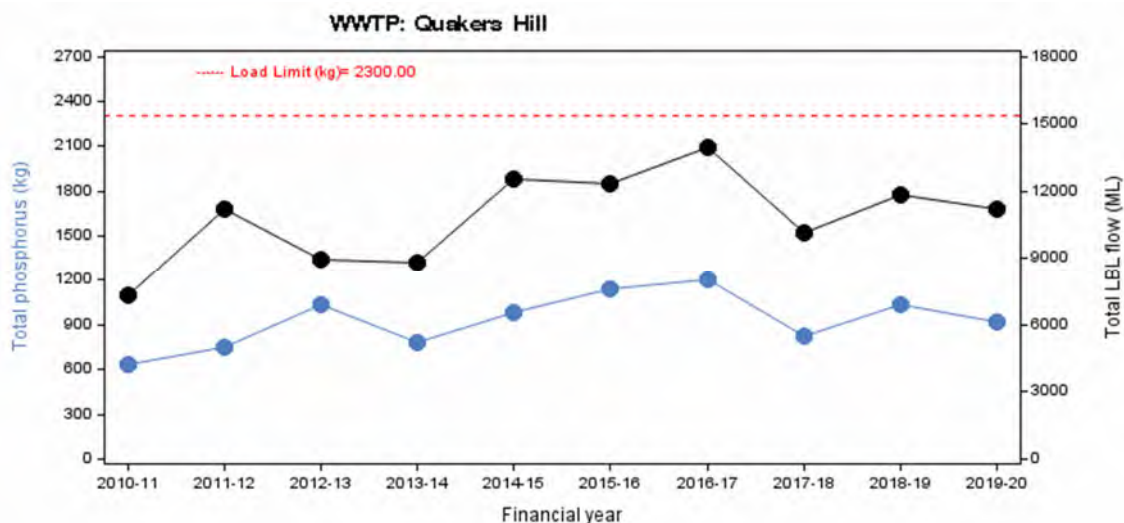
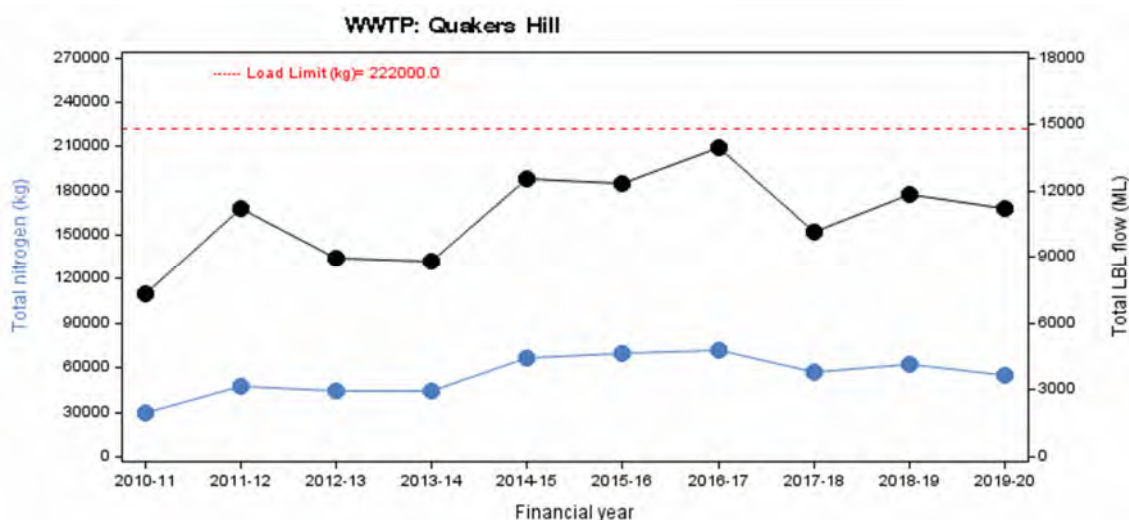
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

Discharge quality: Other chemicals and organics (including pesticides)

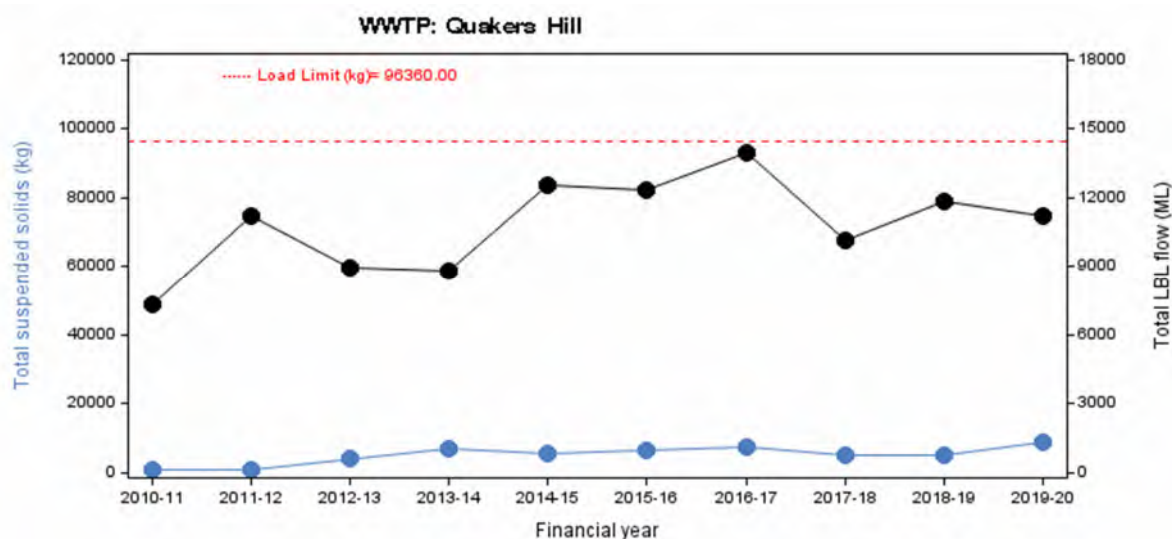
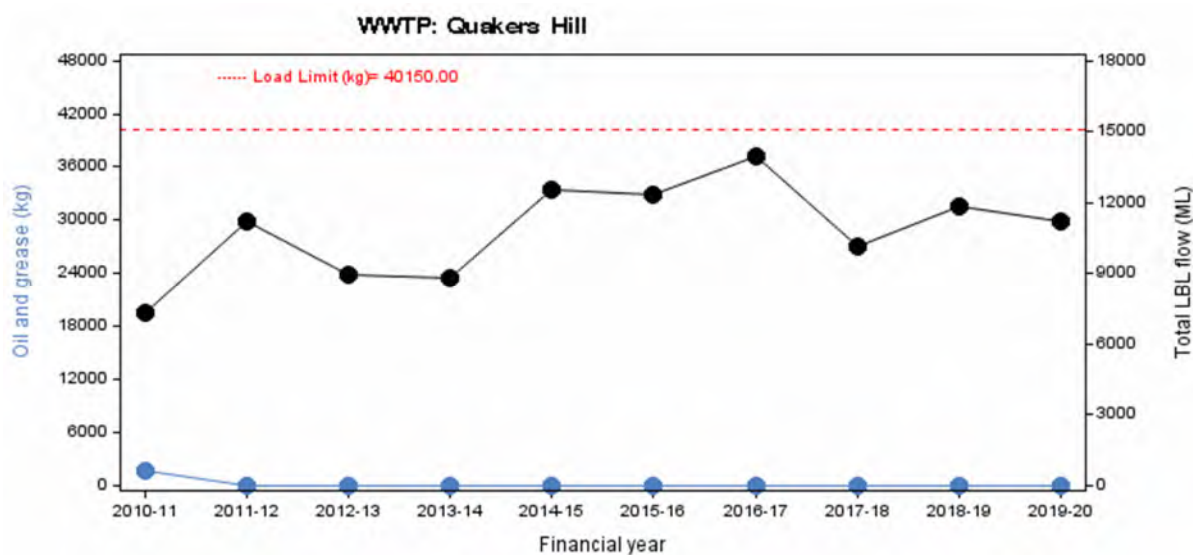
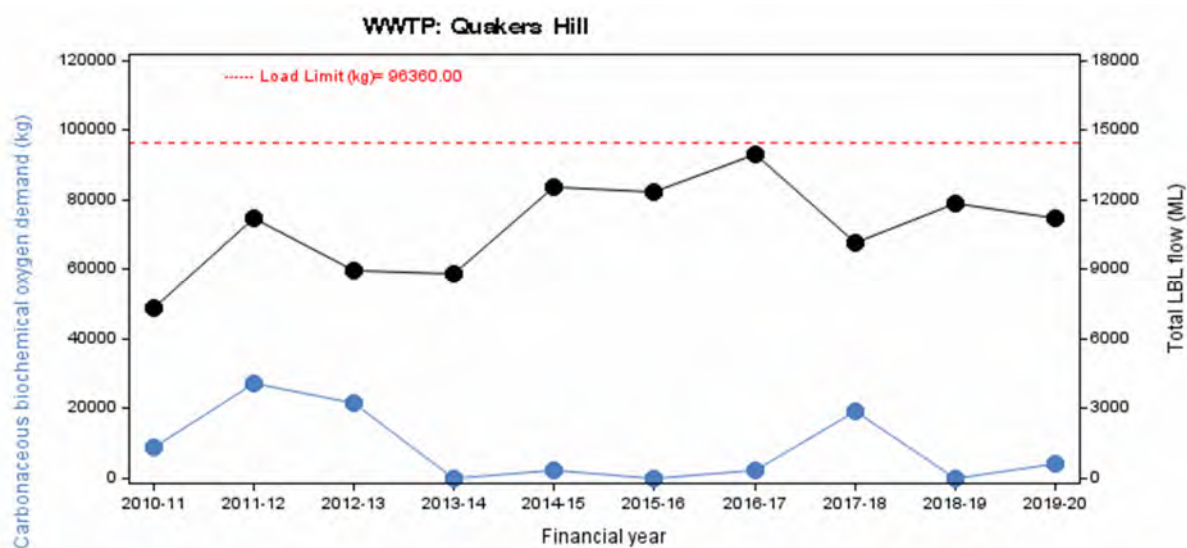


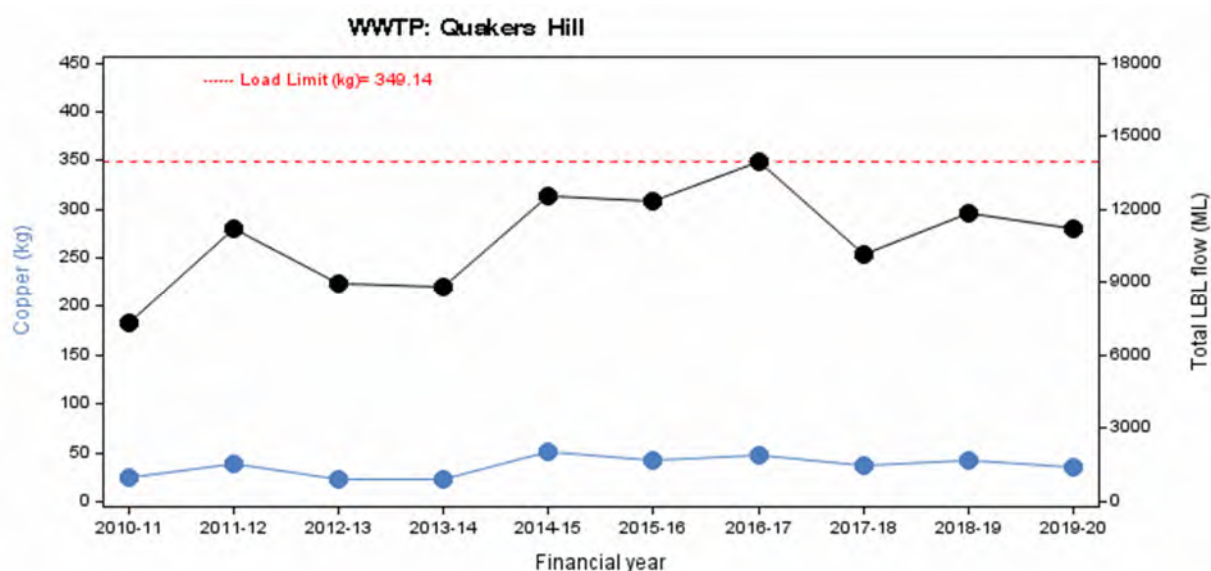
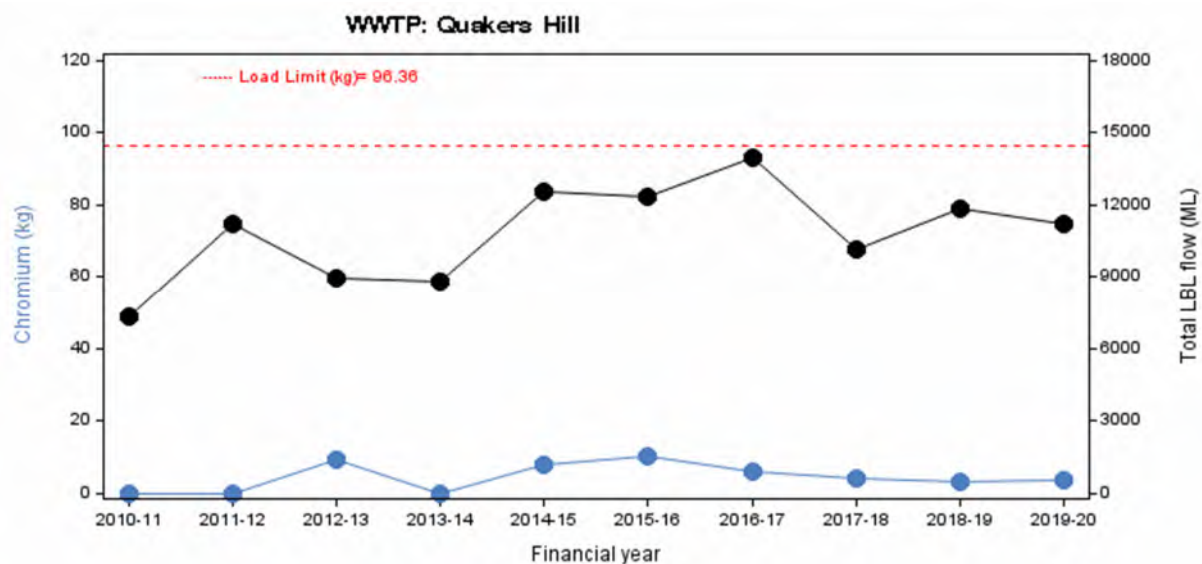
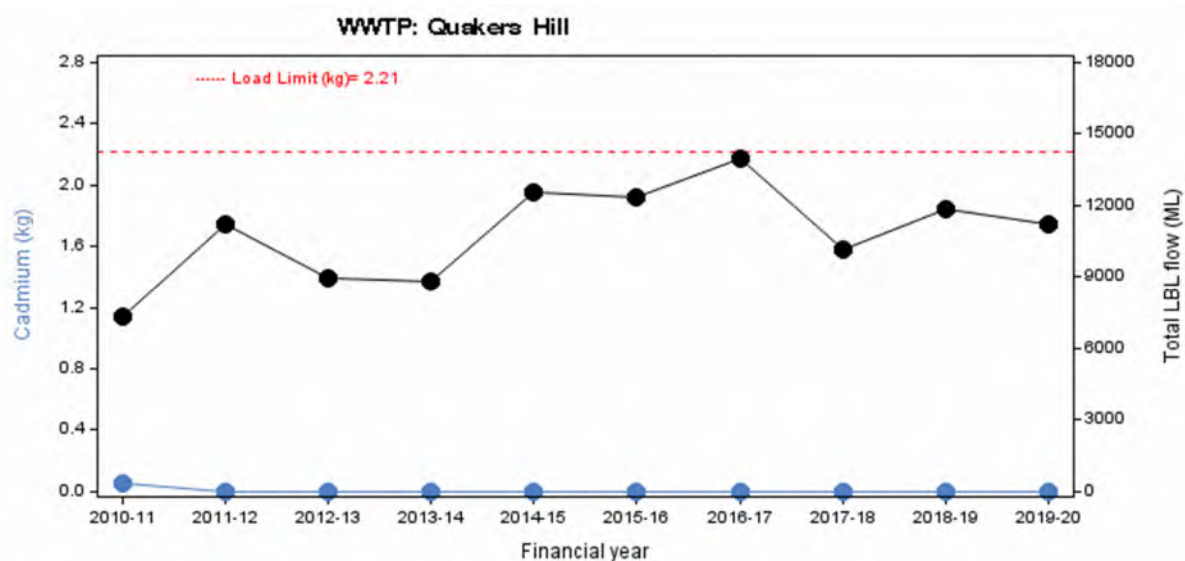
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17. Statistical test was not conducted because >90% of results were below the detection limit.

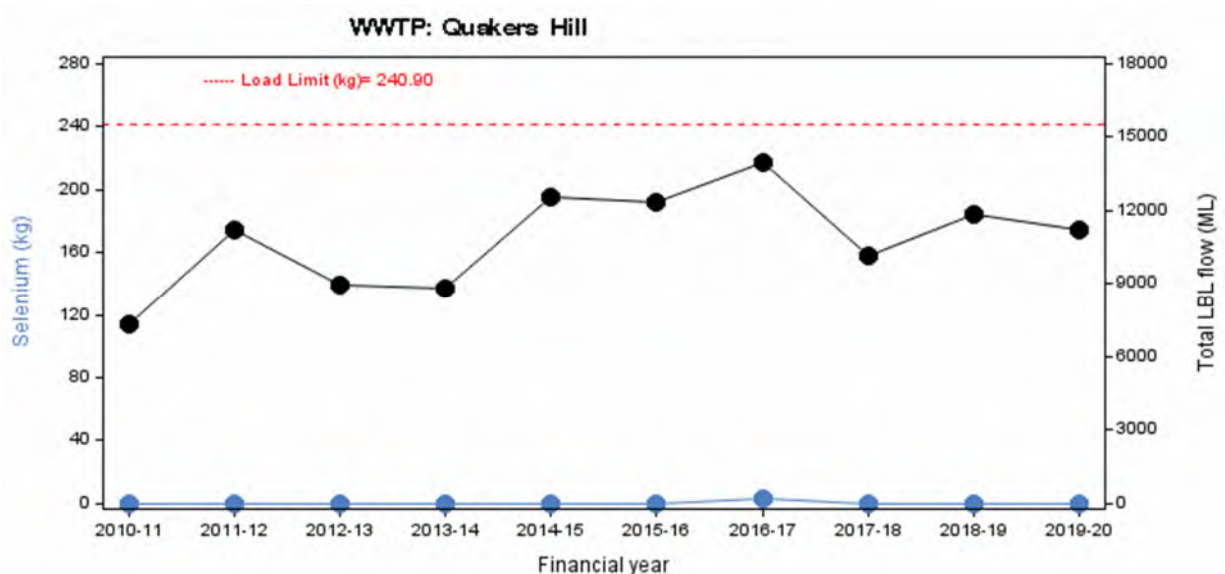
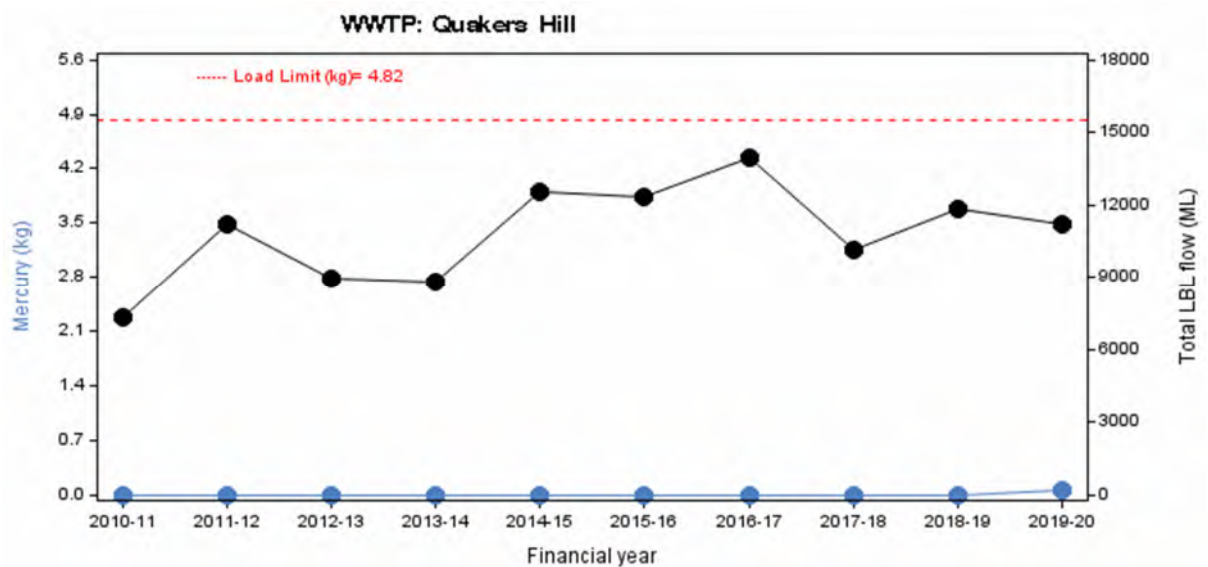
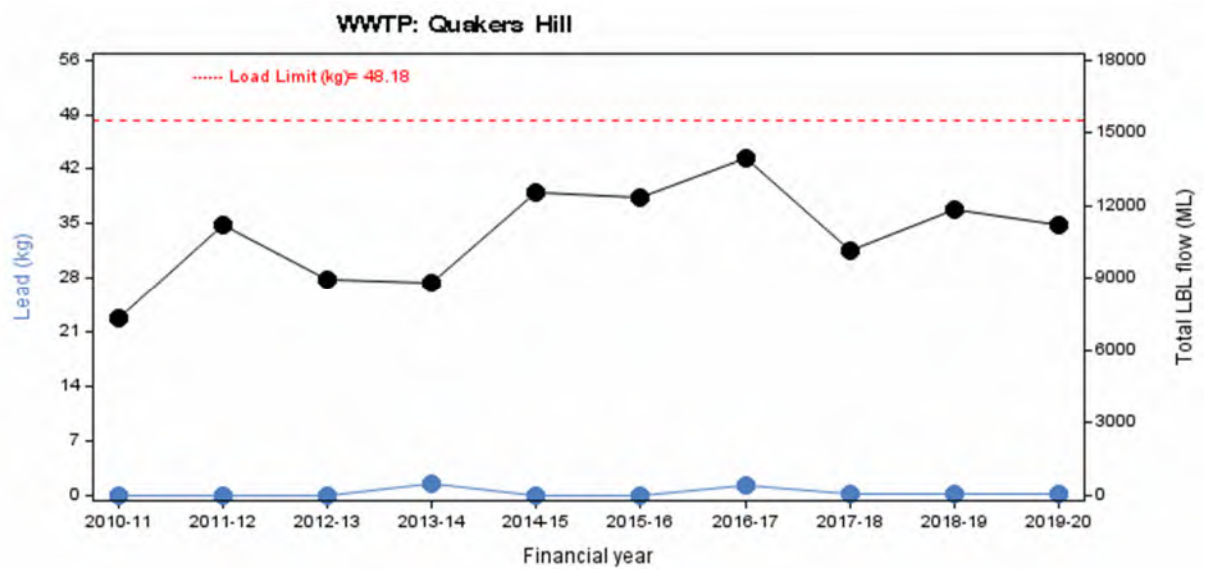
Discharge load: Nutrients

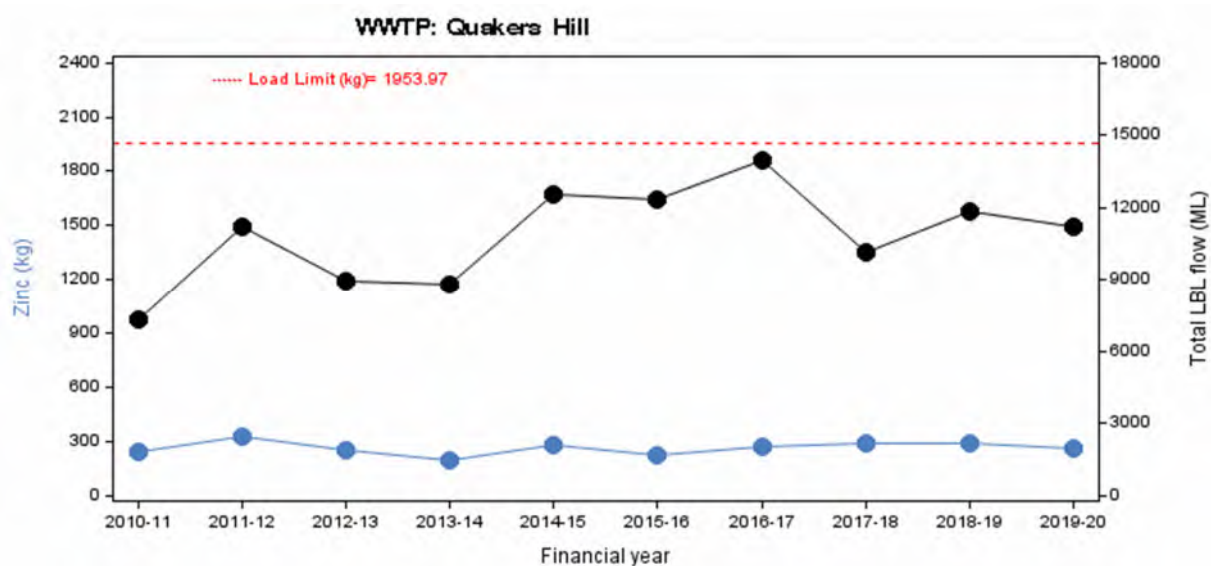


Discharge load: Major conventional analytes

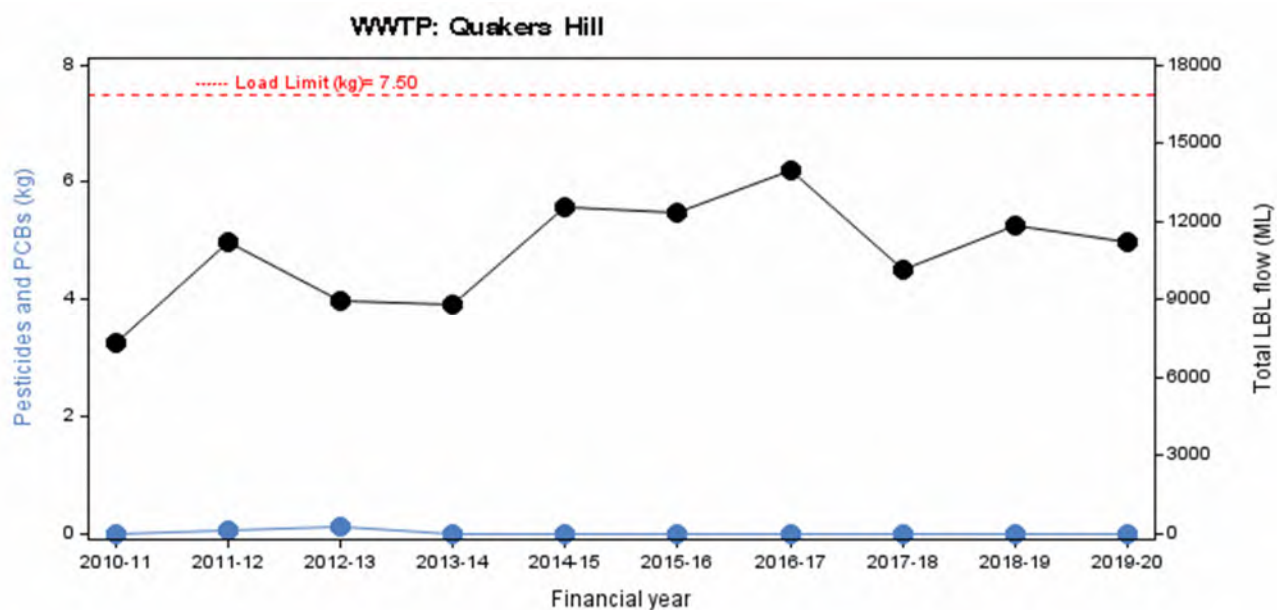






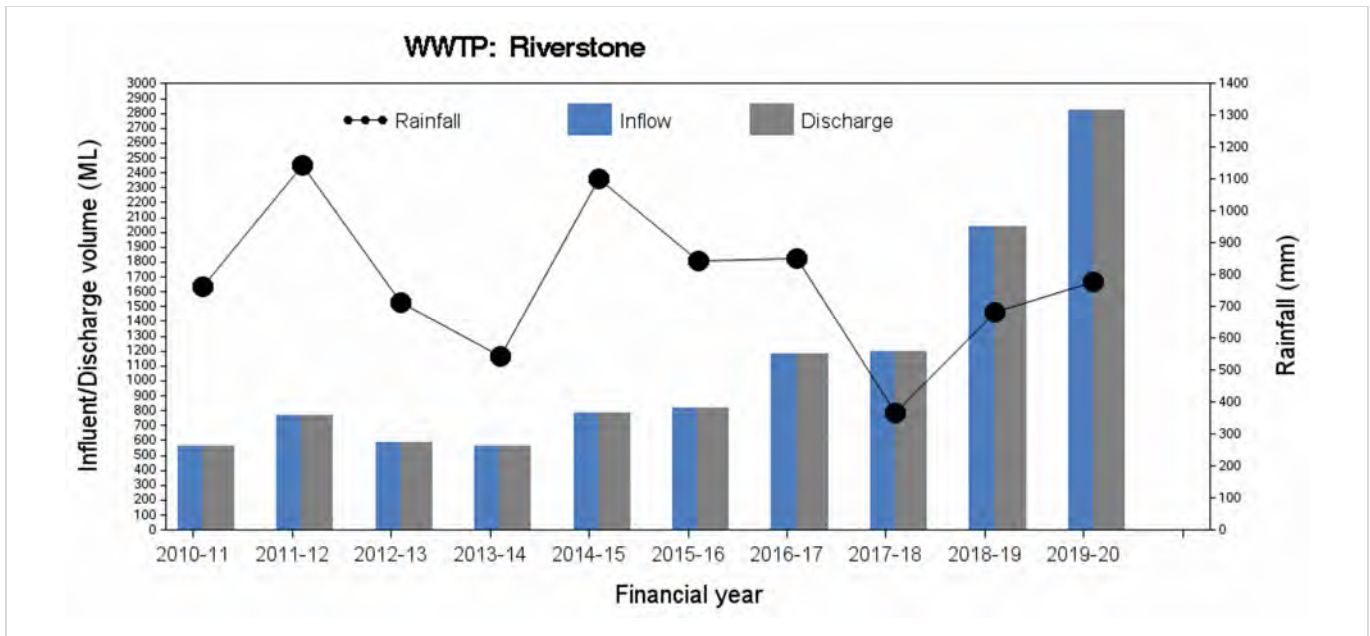


Discharge load: Other chemicals and organics (including pesticides)

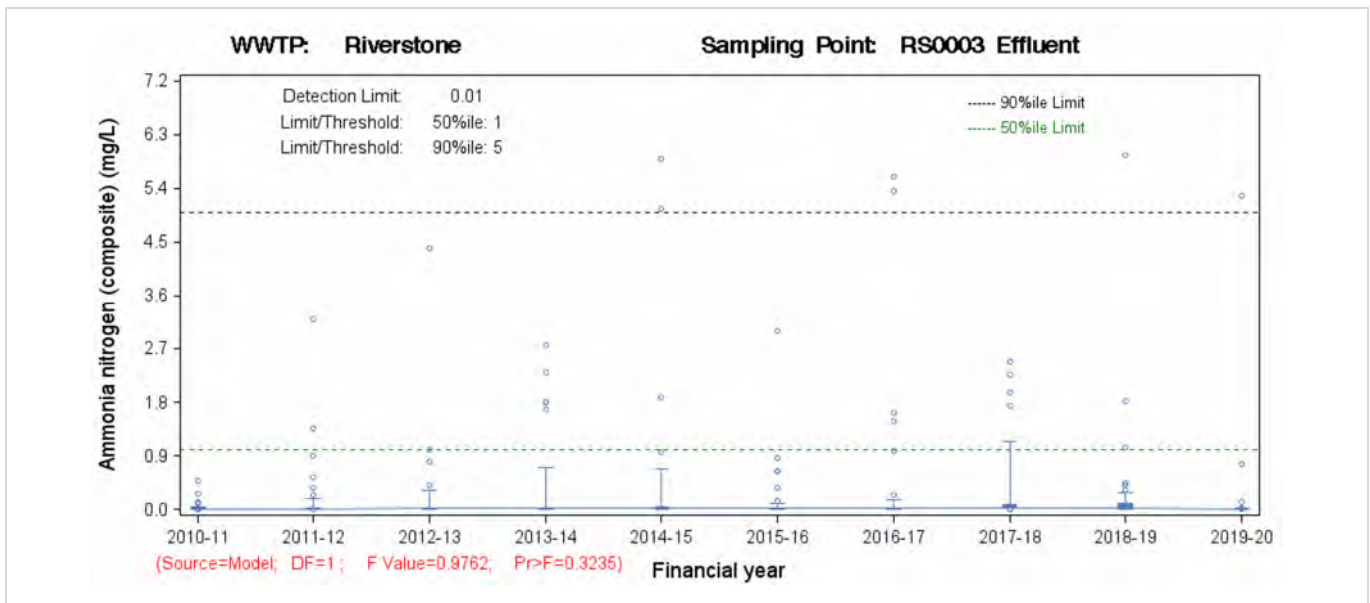


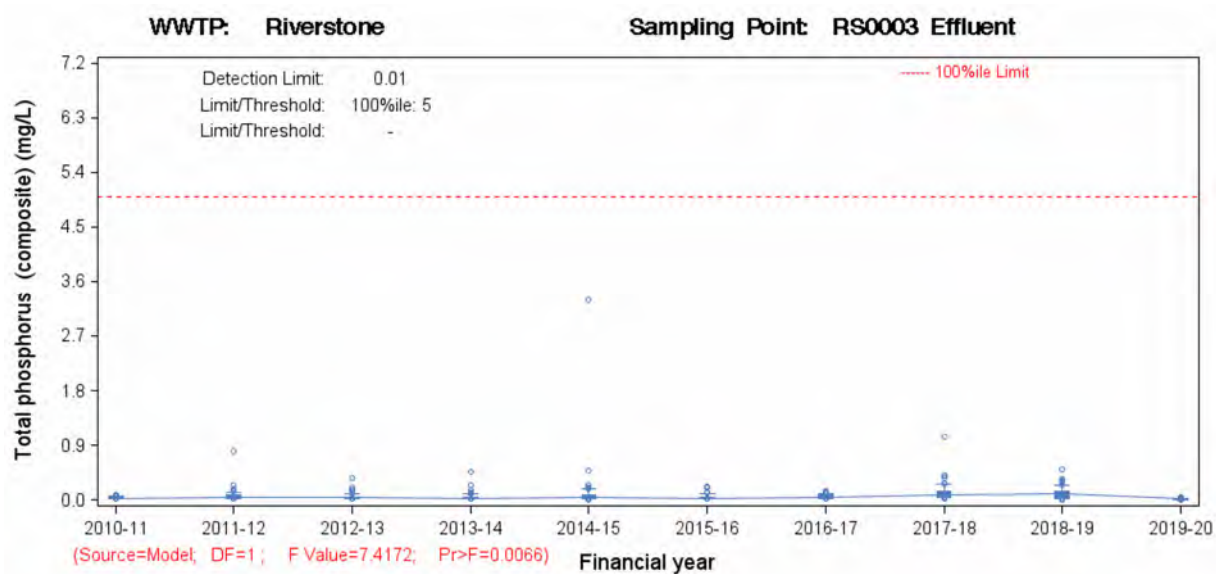
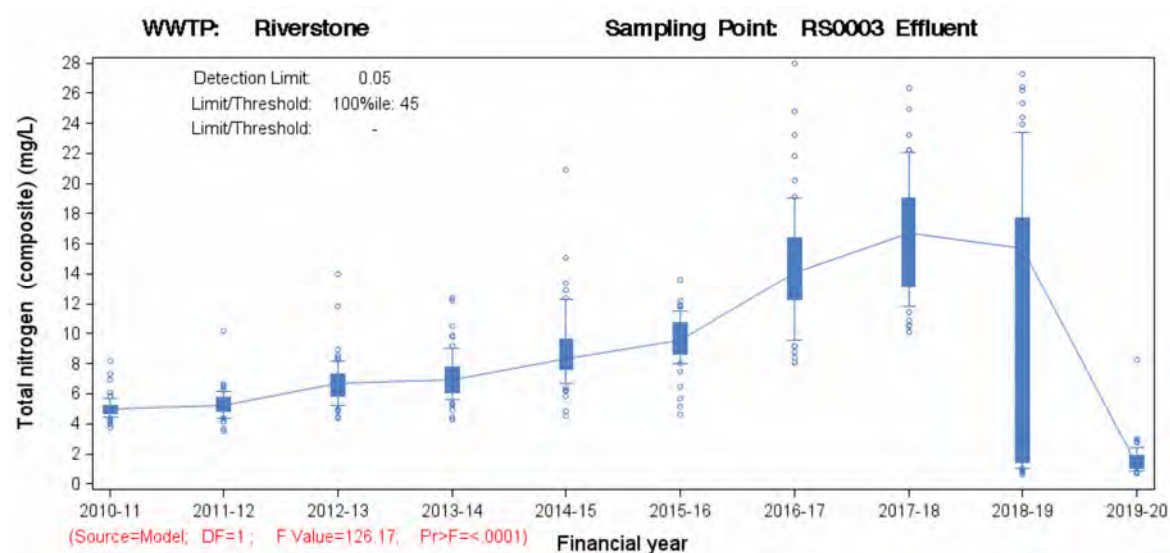
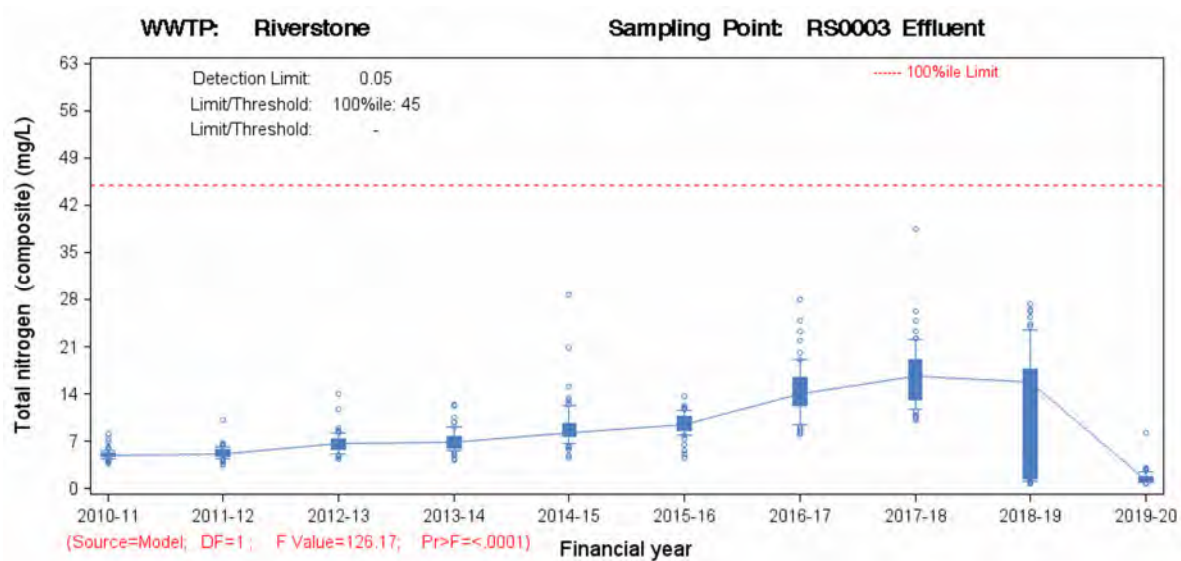
Riverstone WWTP

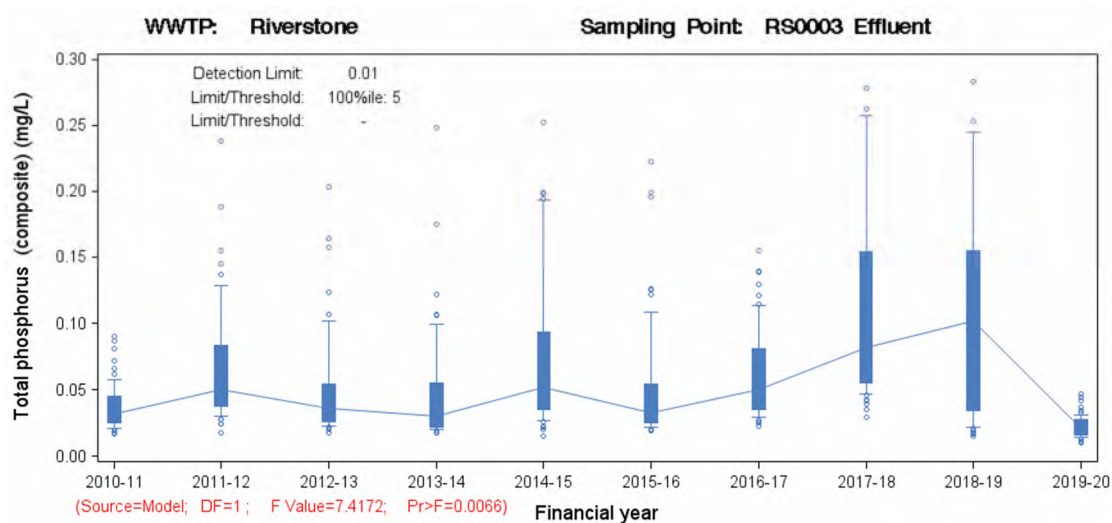
Discharge volume and rainfall



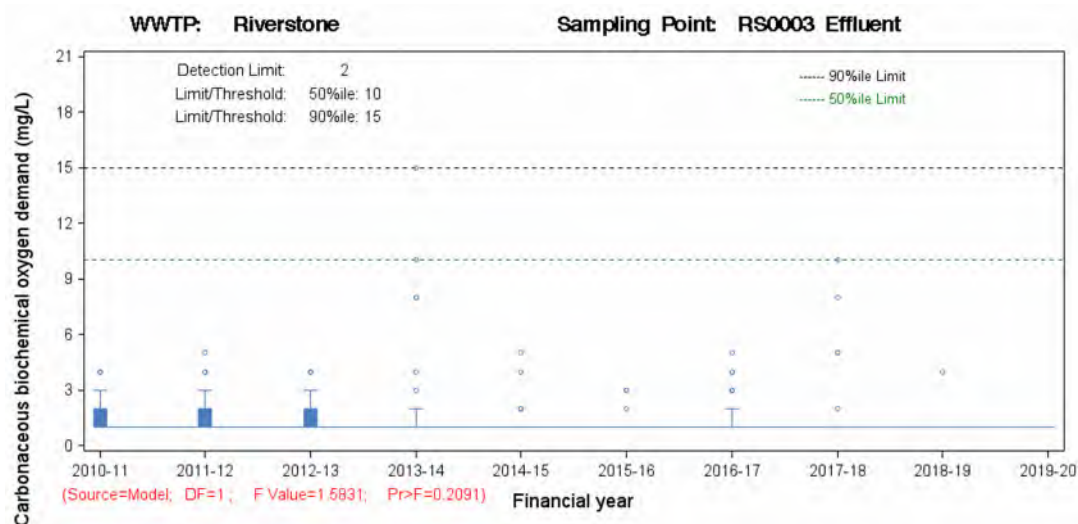
Discharge quality: Nutrients



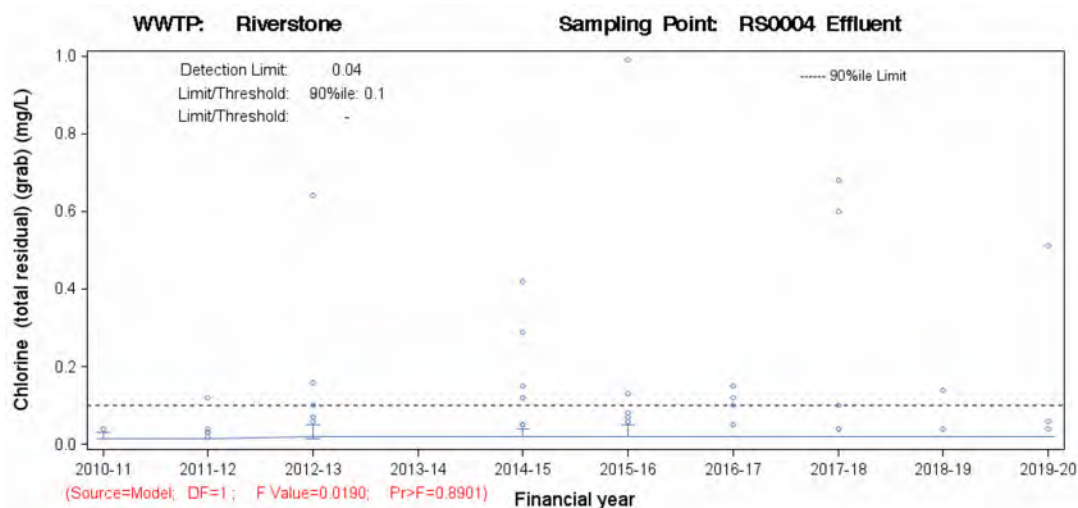


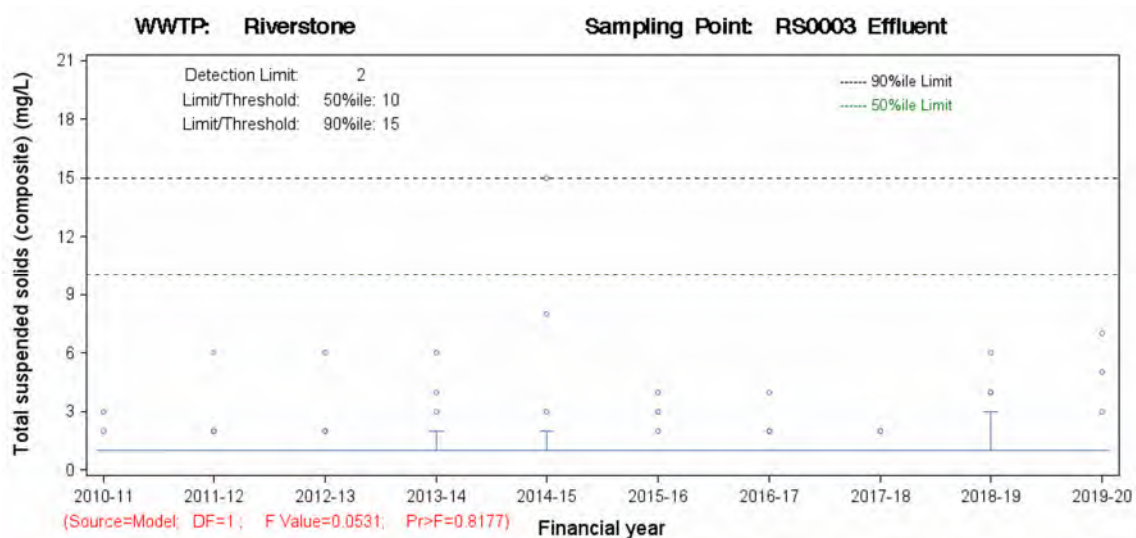
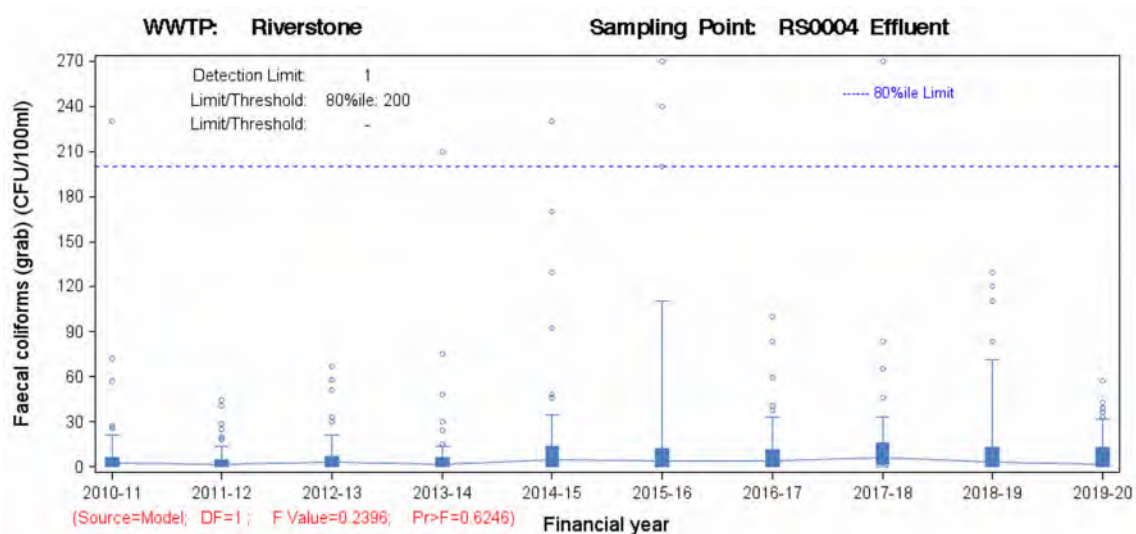


Discharge quality: Major conventional analytes

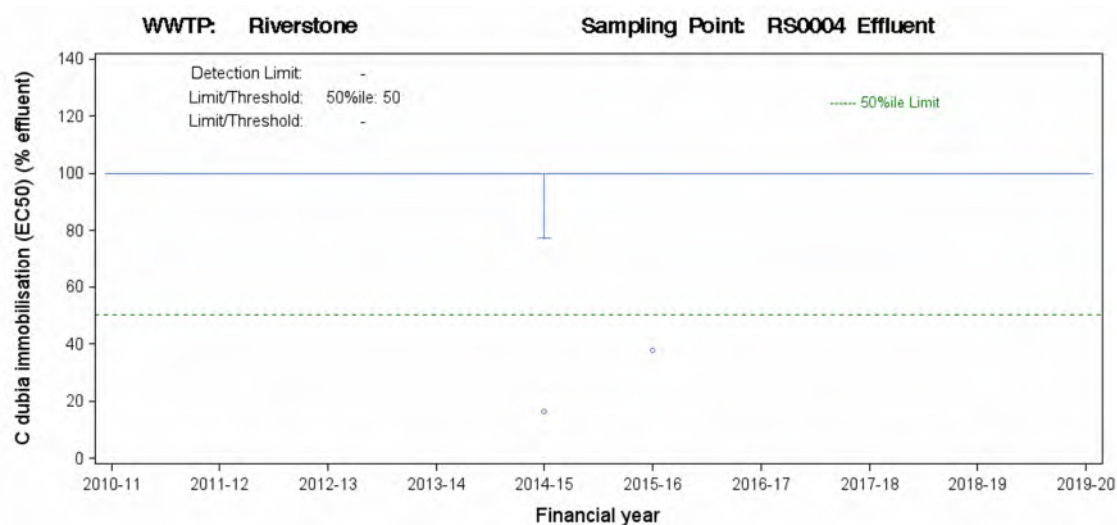


Note: Statistical test was based on 2019-20 data with previous five years data (2014-2019) due to lab method change in 2014-15.

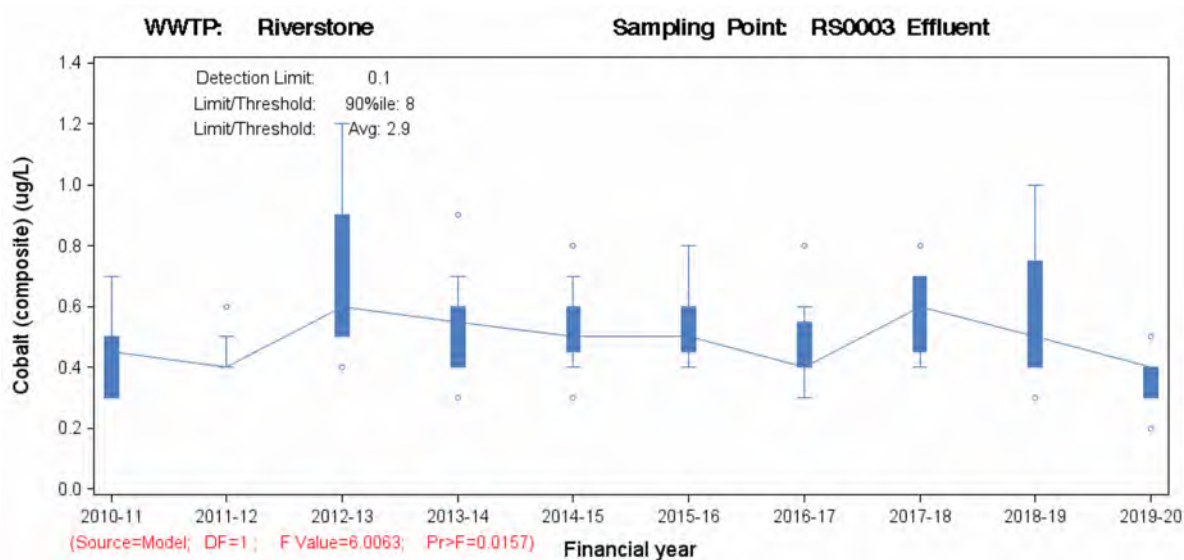
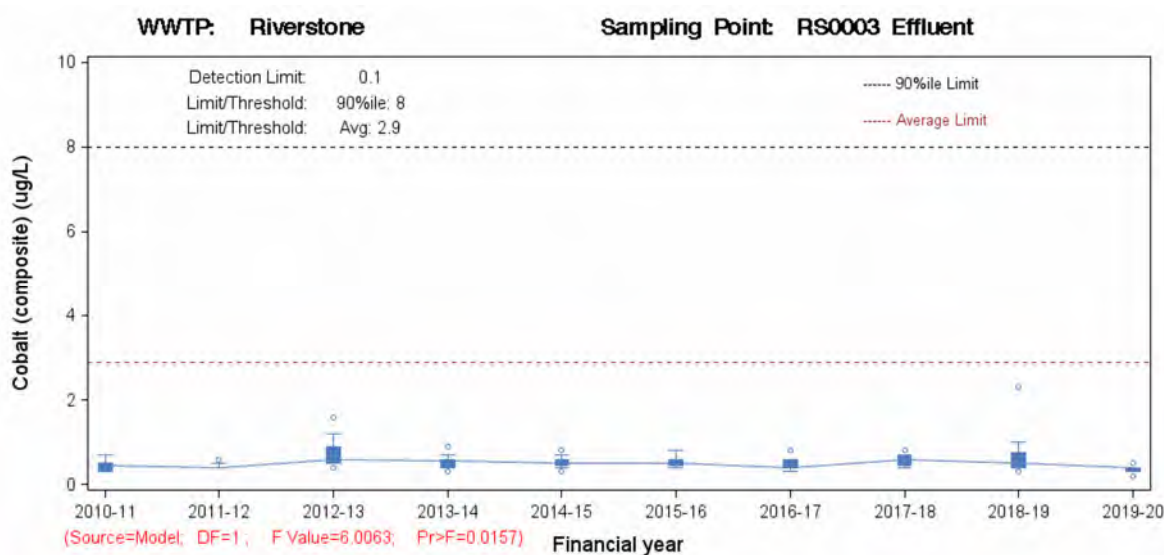
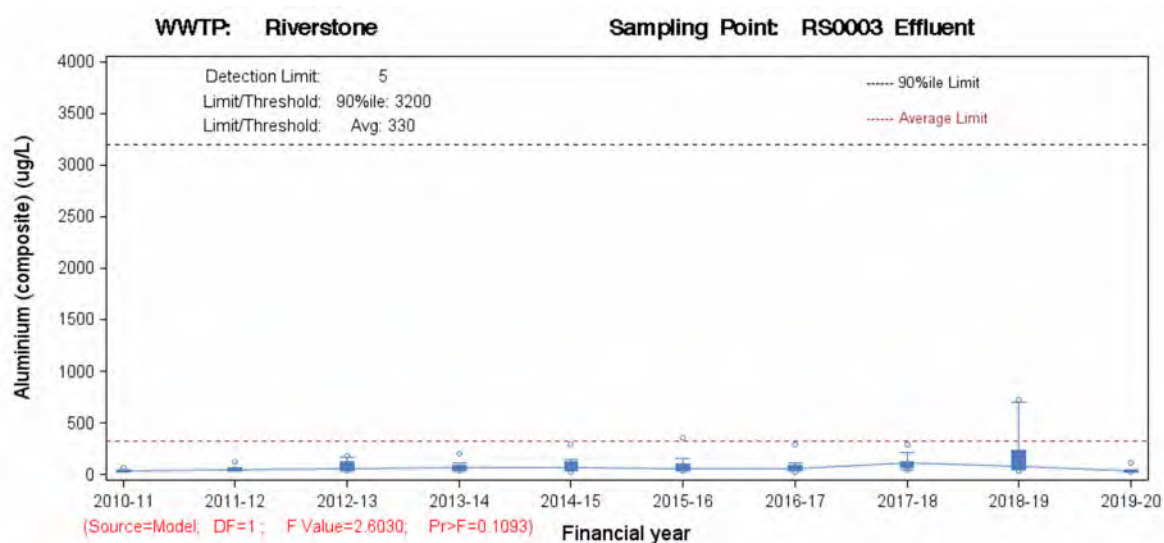


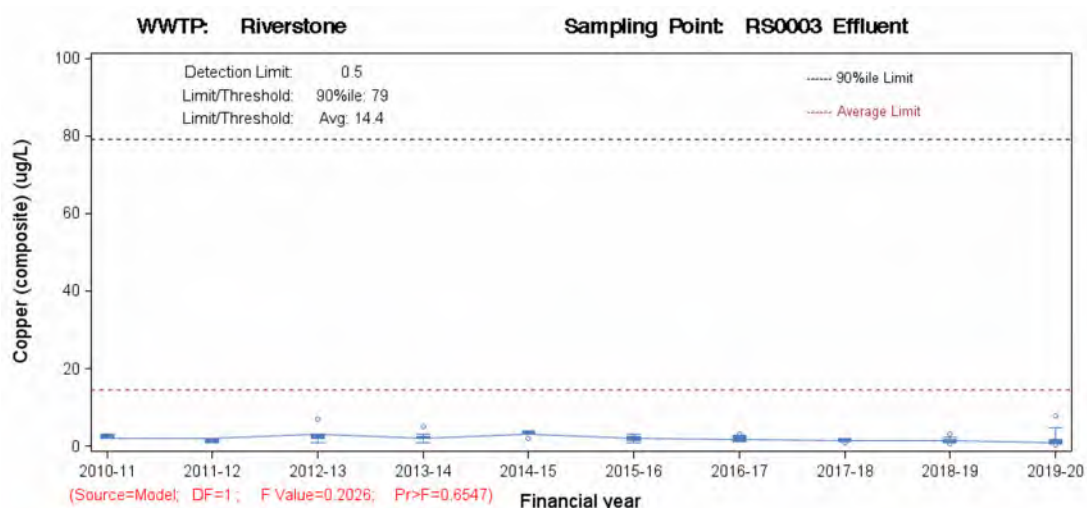


Discharge quality: Toxicity

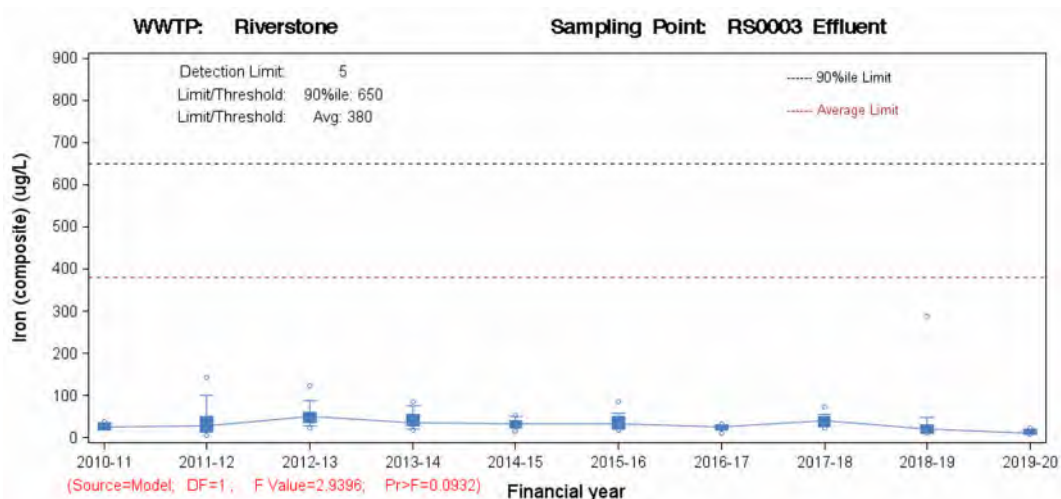


Note: Statistical test was not conducted because >90% of results were recorded at 100% survival for *Ceriodaphnia dubia*.

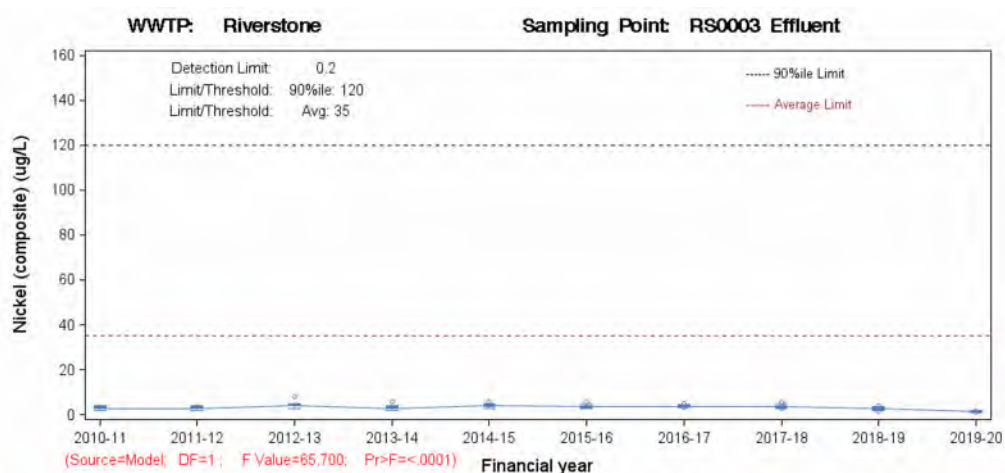




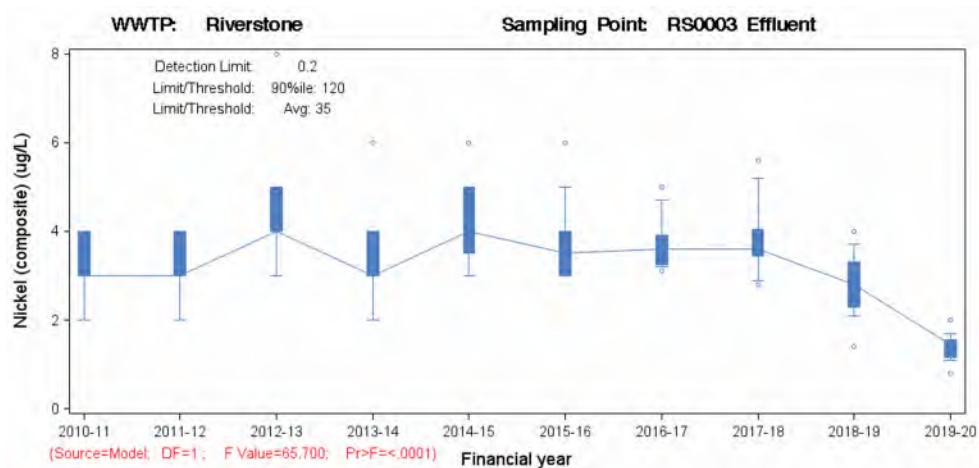
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.



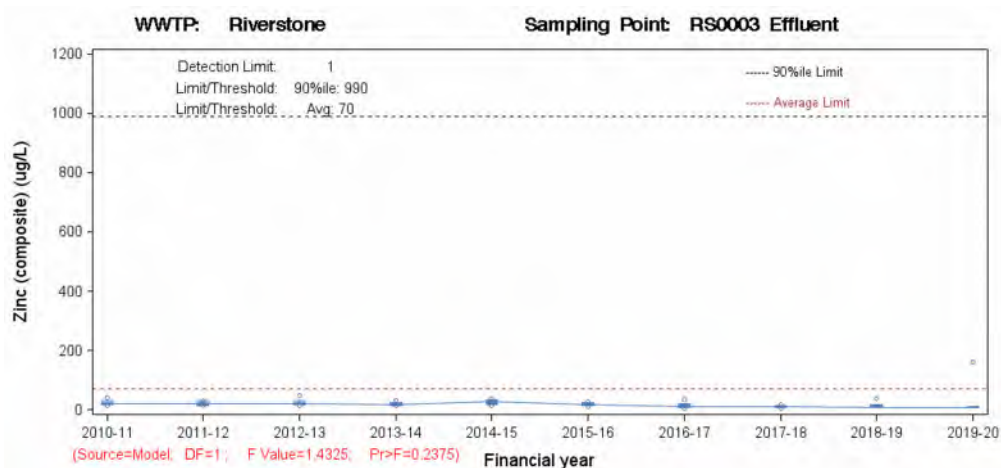
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.



Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

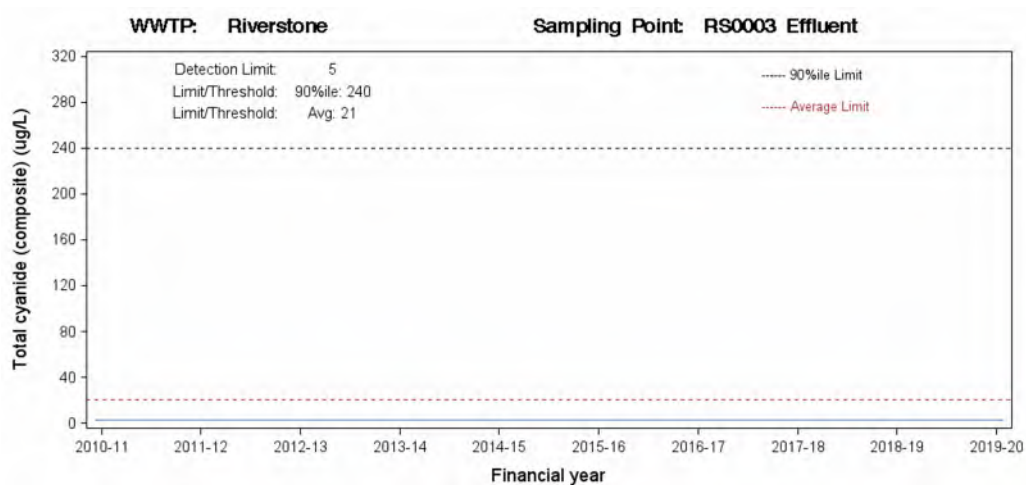


Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

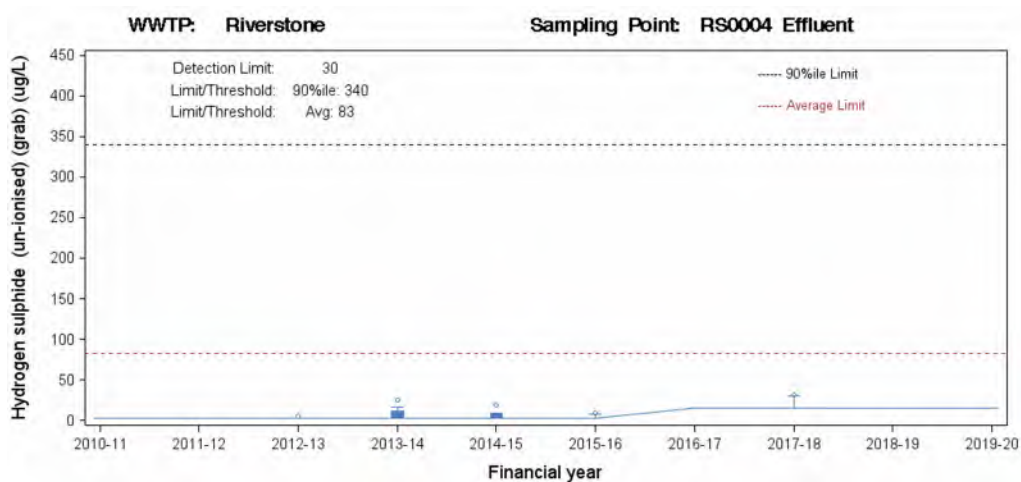


Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

Discharge quality: Other chemicals and organics (including pesticides)

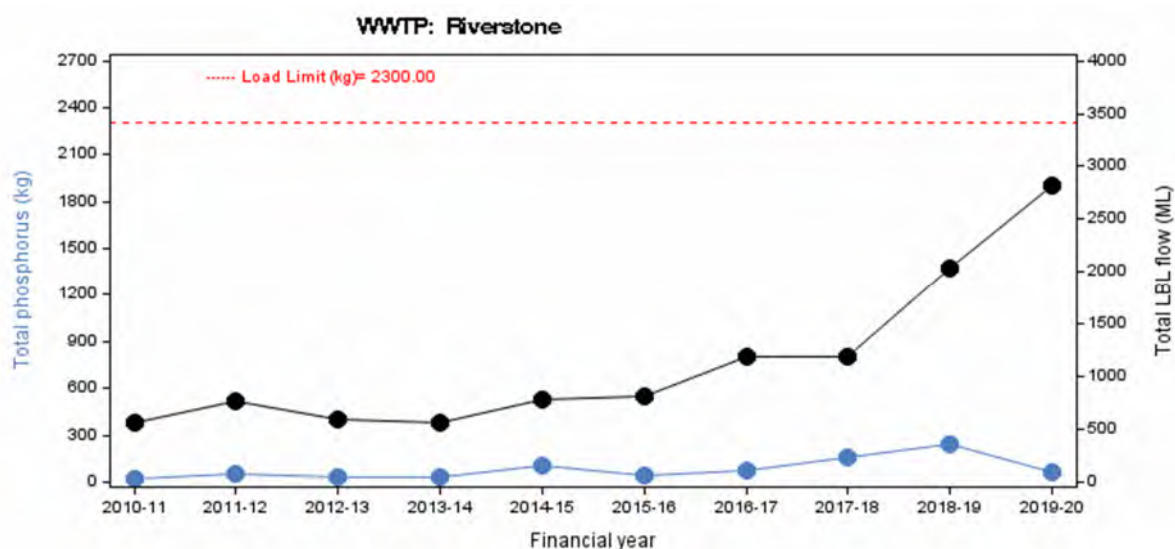
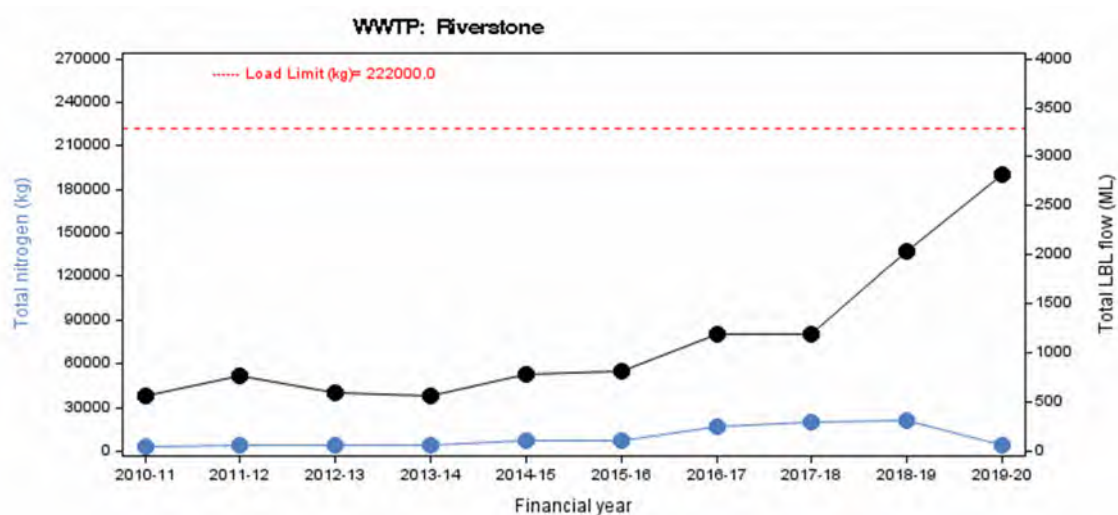


Note: Statistical test was not conducted because >90% of results were below the detection limit.

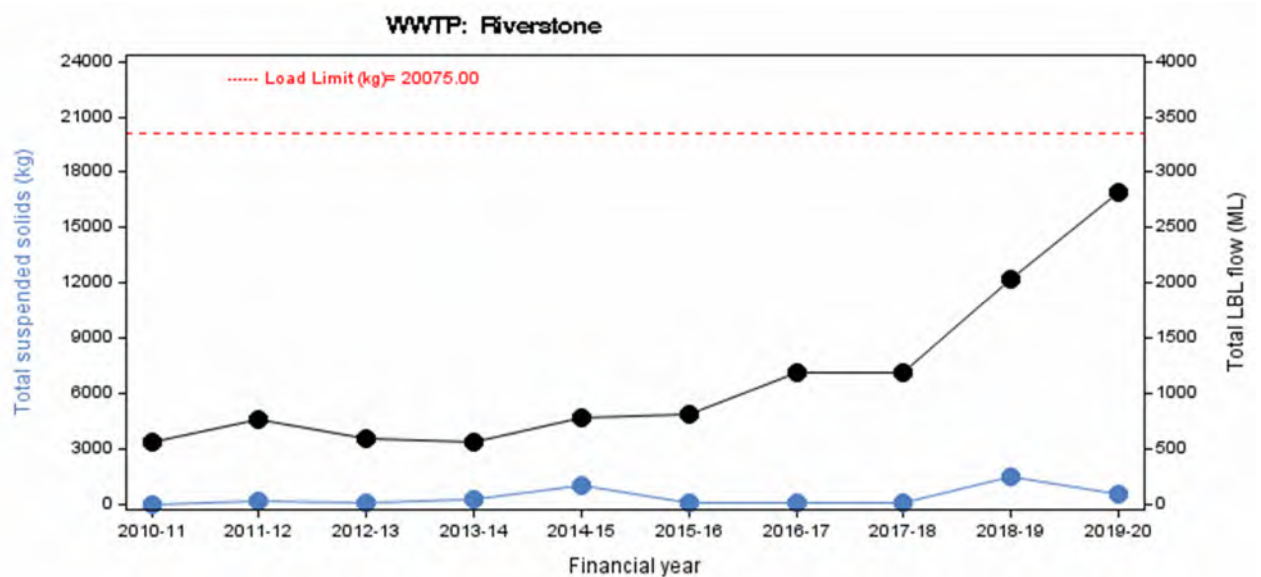
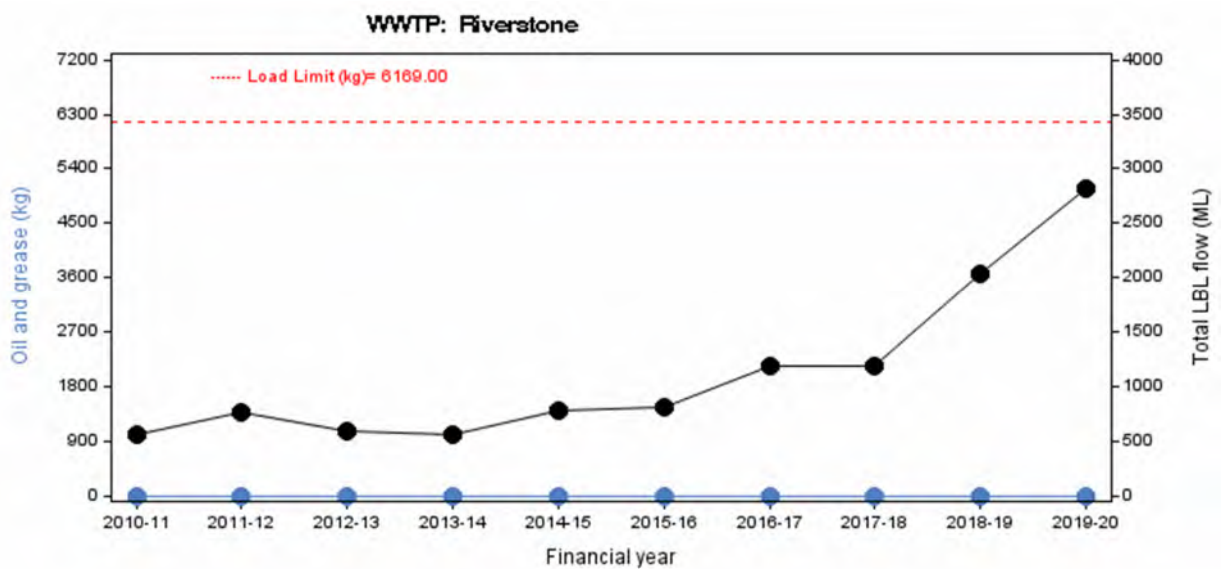
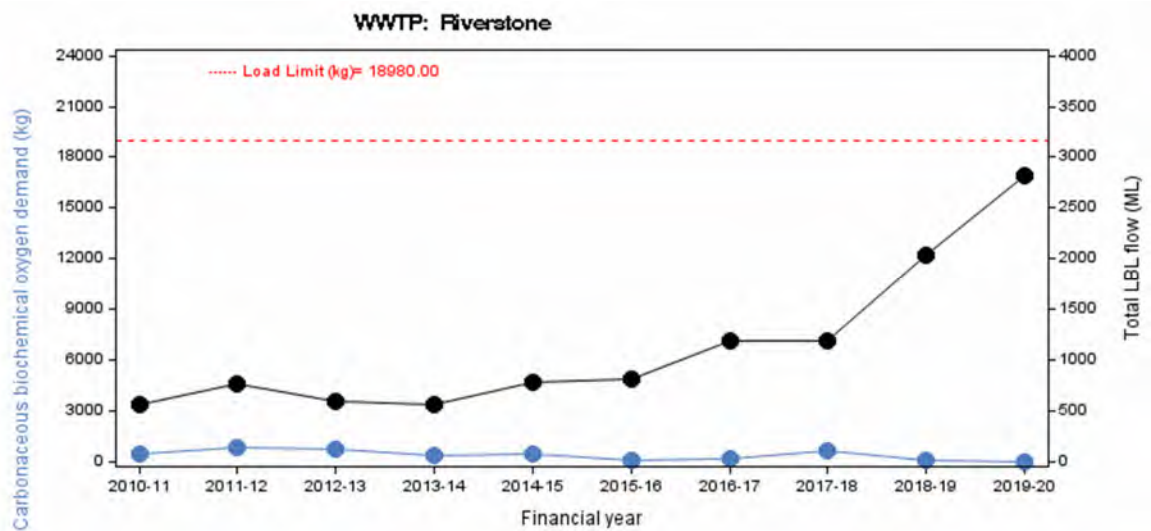


Note: 2019-20 data was compared with previous three years data (2016-2019) due to lab method change in 2016-17. Statistical test was not conducted because >90% of results were below the detection limit.

Discharge load: Nutrients

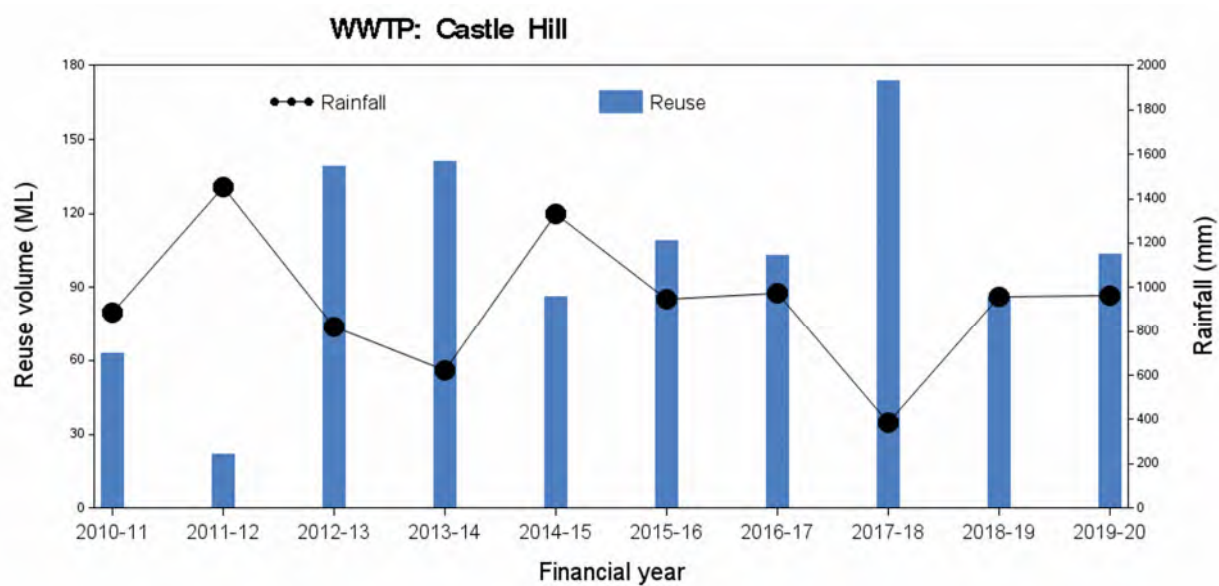
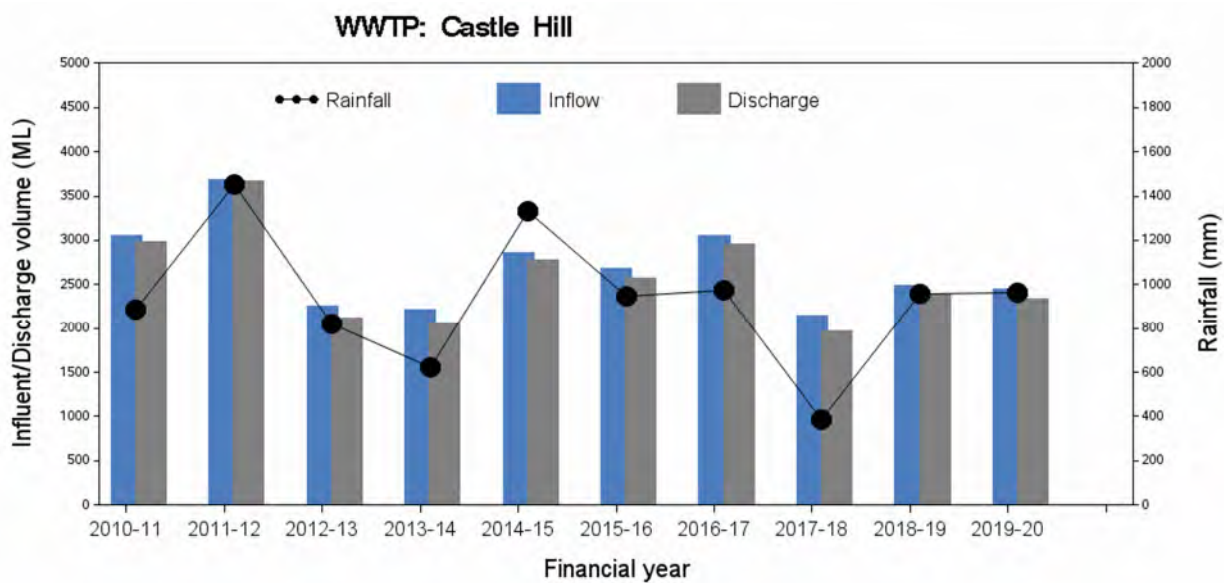


Discharge load: Major conventional analytes

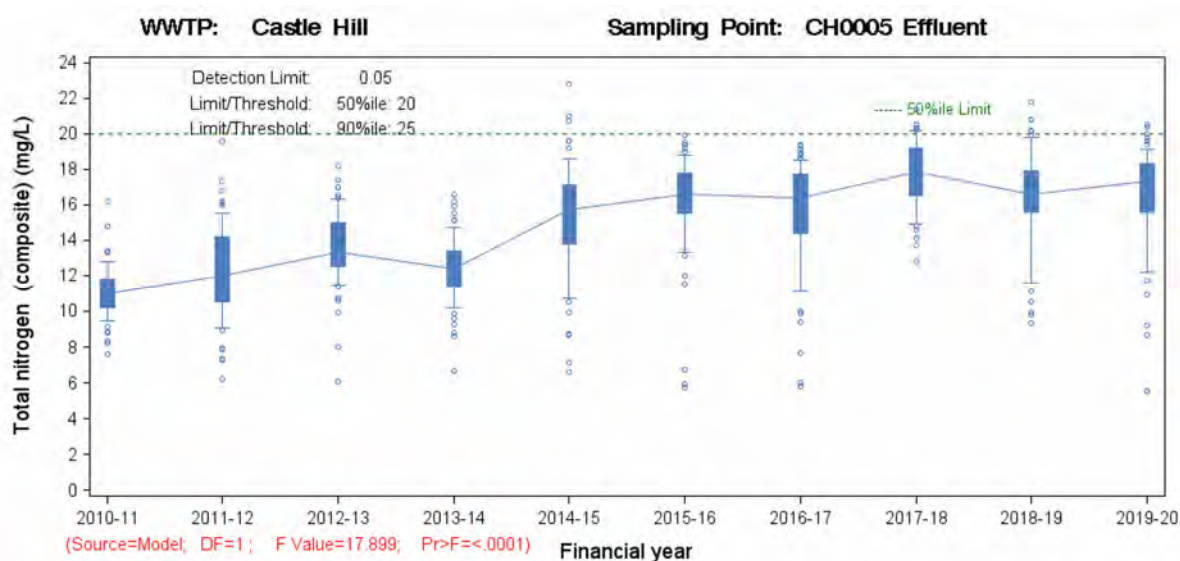
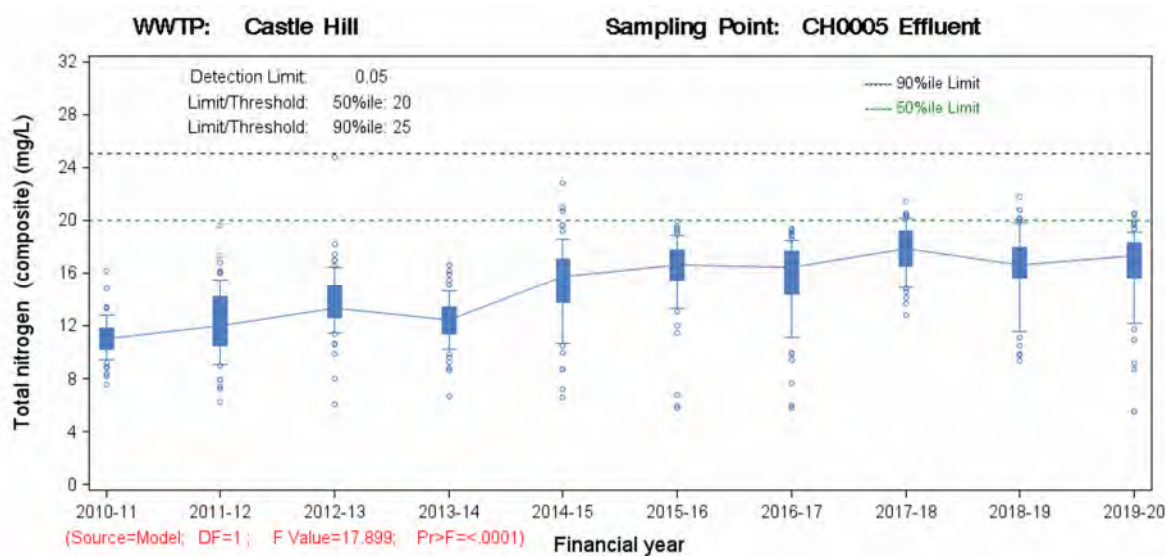
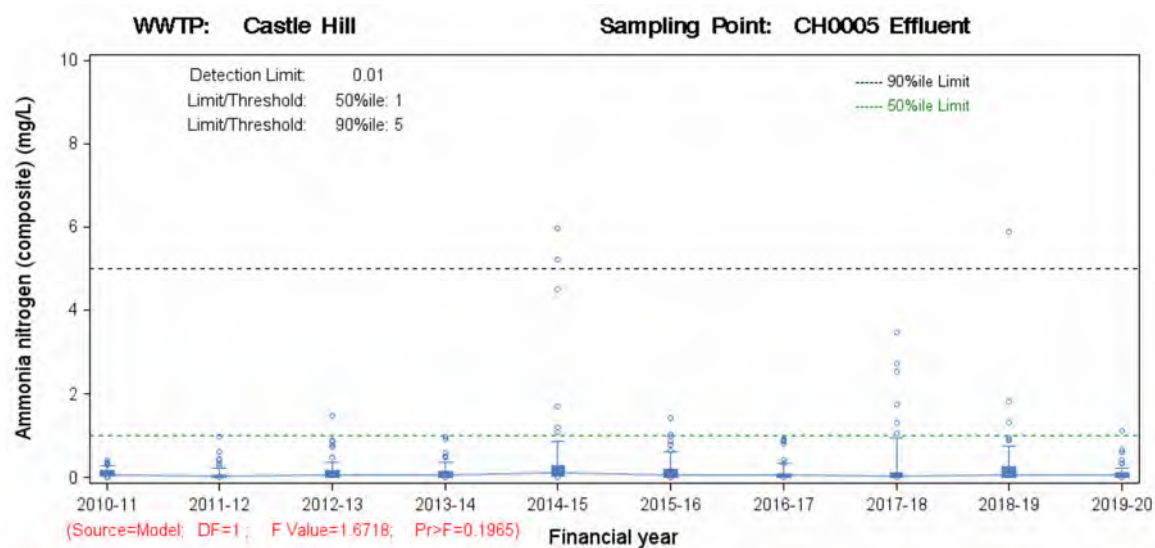


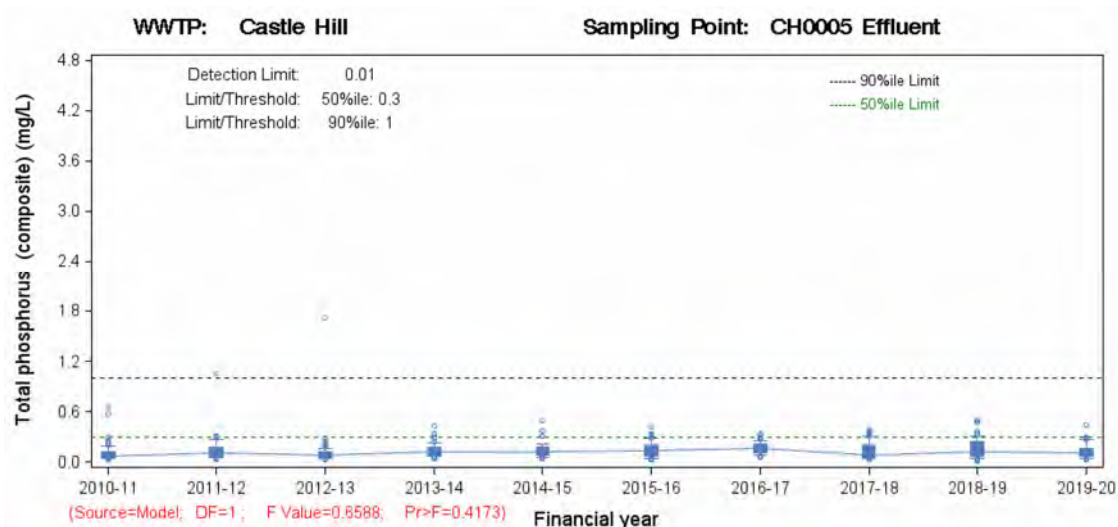
Castle Hill WWTP

Discharge volume and rainfall

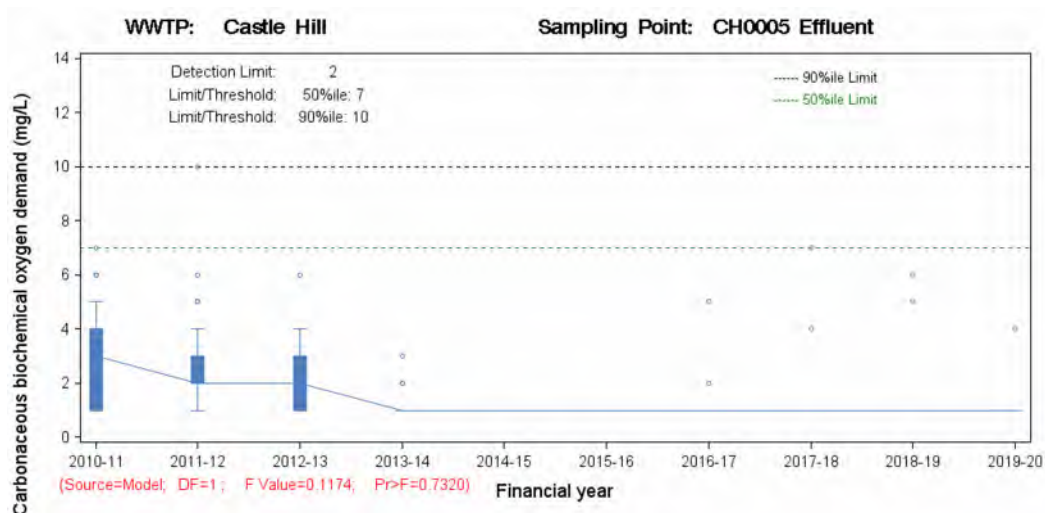


Discharge quality: Nutrients

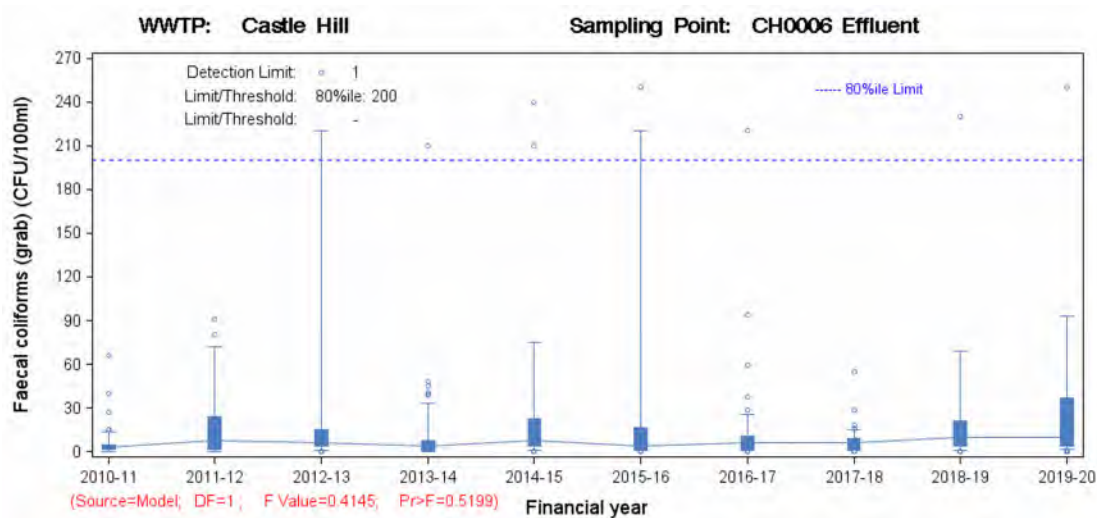


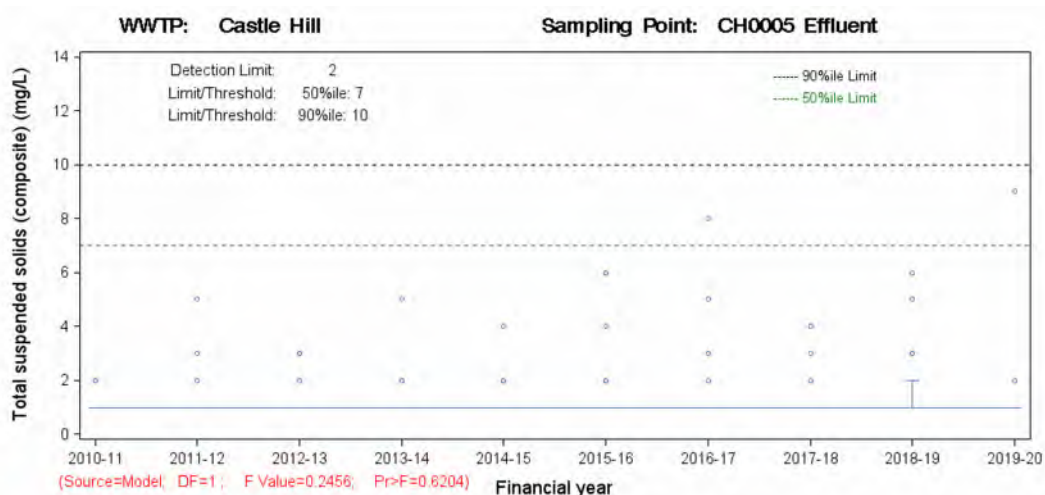


Discharge quality: Major conventional analytes

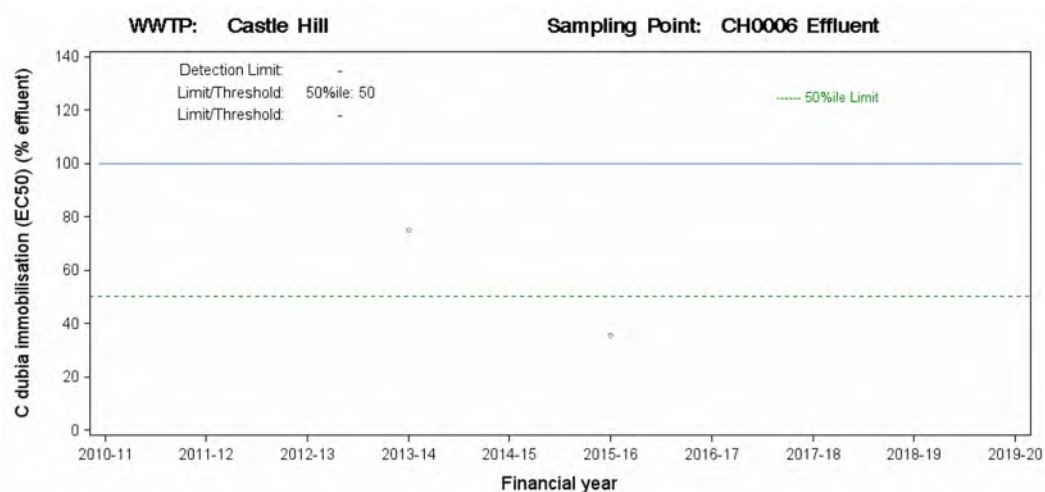


Note: Statistical test was based on 2019-20 data with previous five years data (2014-2019) due to lab method change in 2014-15.



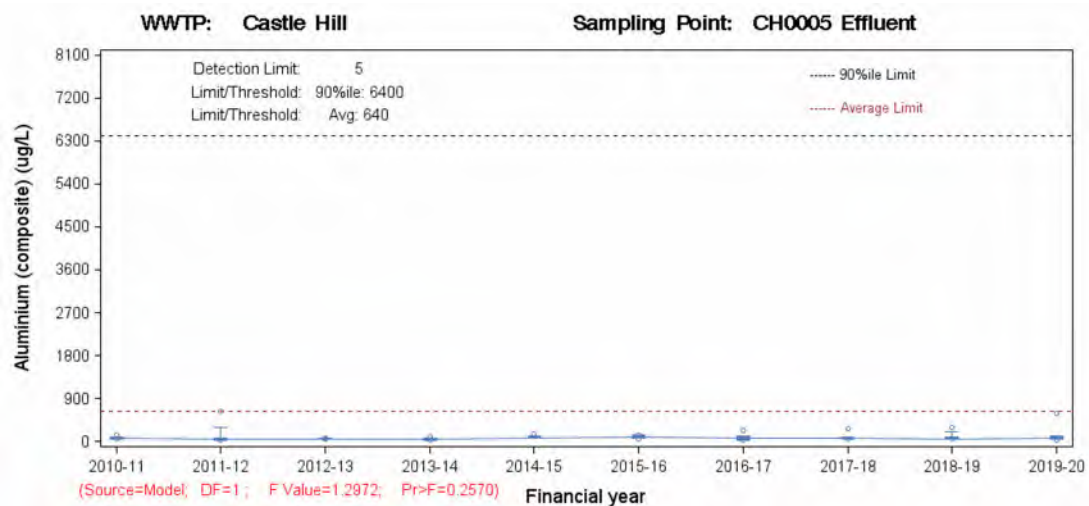


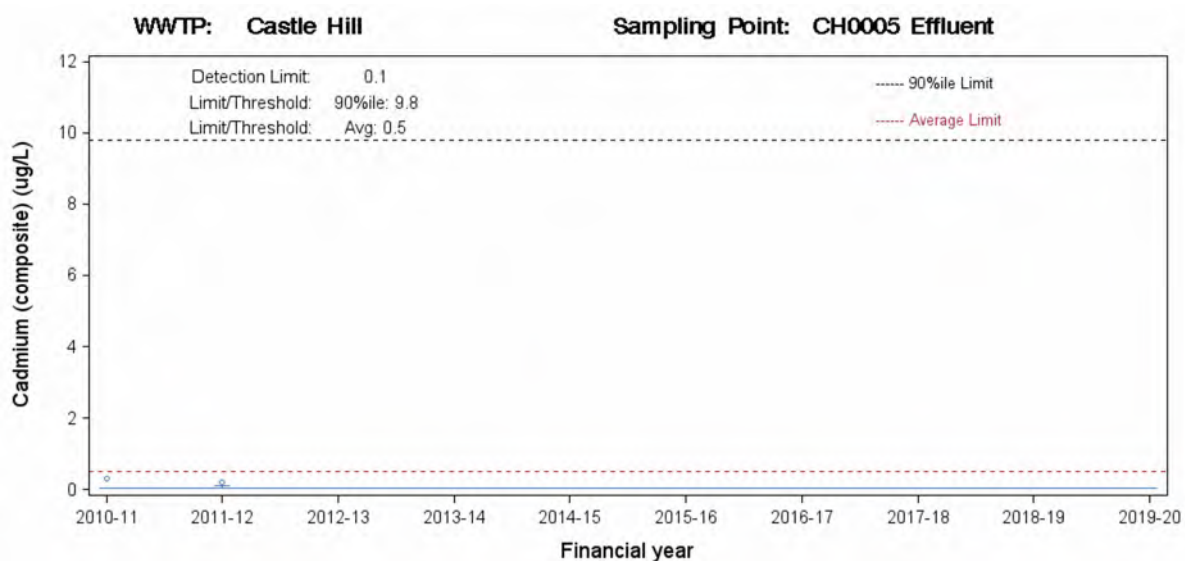
Discharge quality: Toxicity



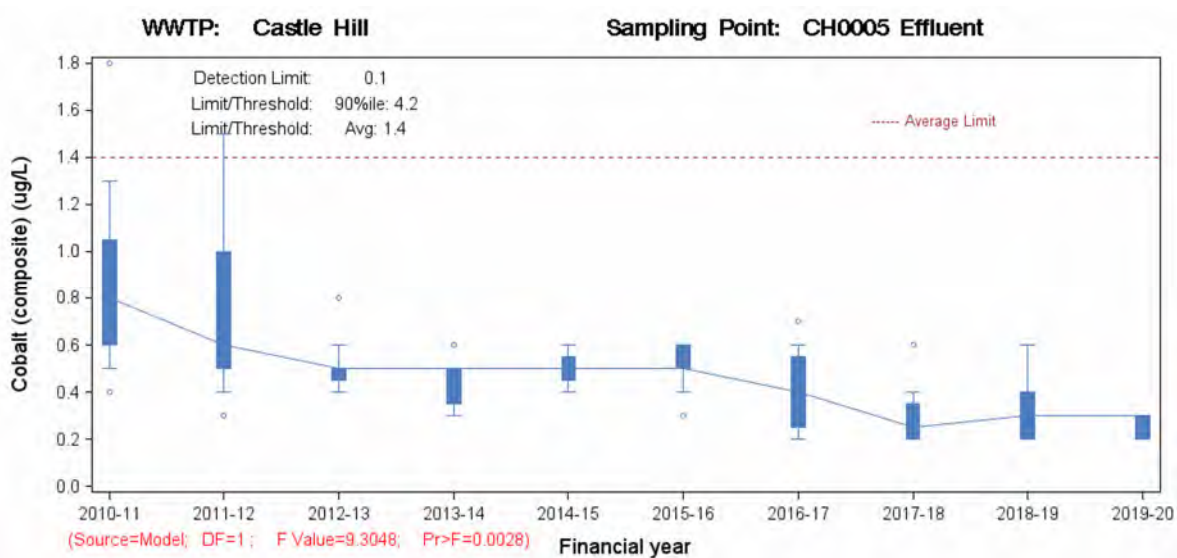
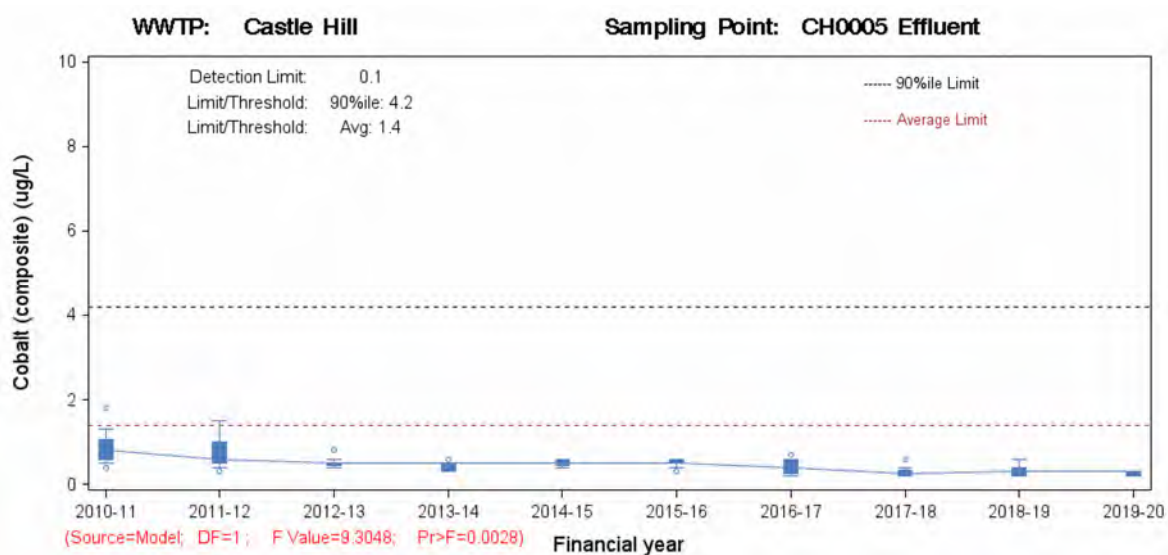
Note: Statistical test was not conducted because >90% of results were recorded at 100% survival for *Ceriodaphnia dubia*.

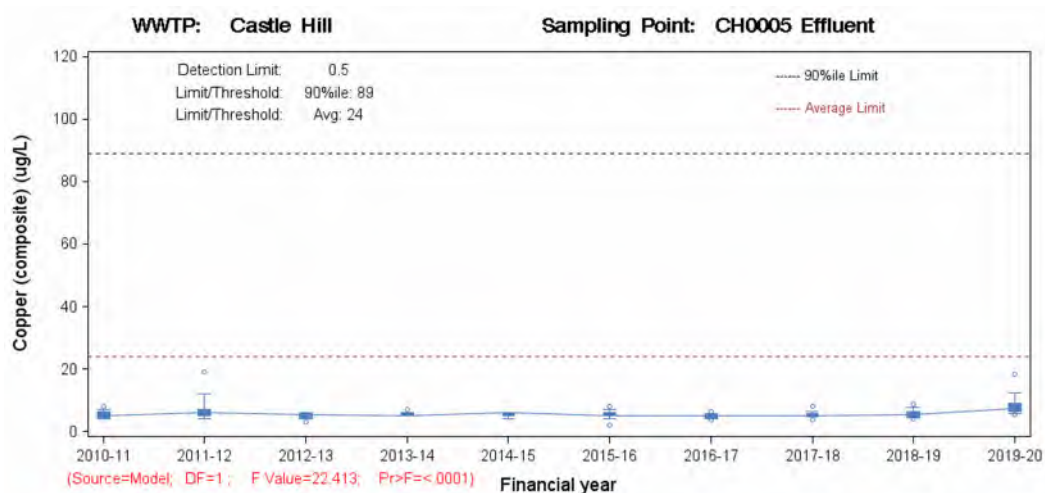
Discharge quality: Trace metals



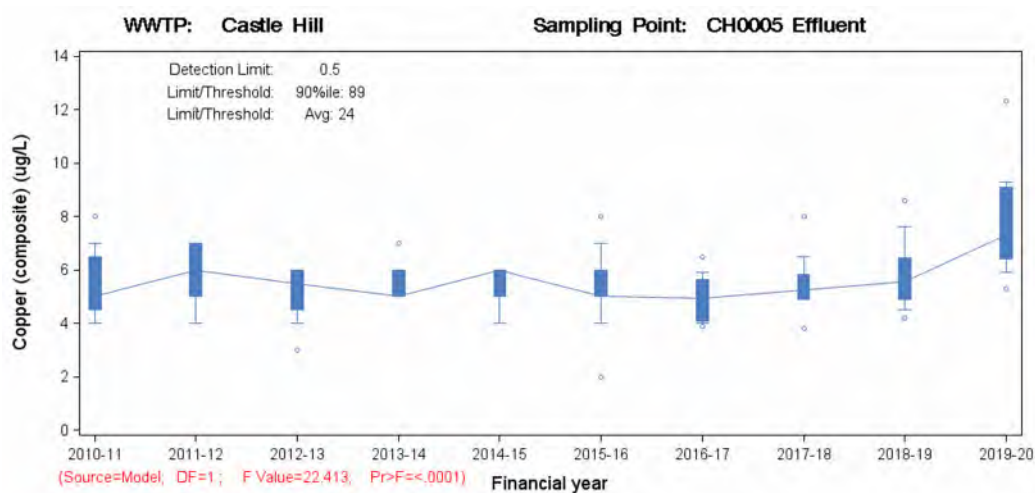


Note: Statistical test was not conducted because >90% of results were below the detection limit.

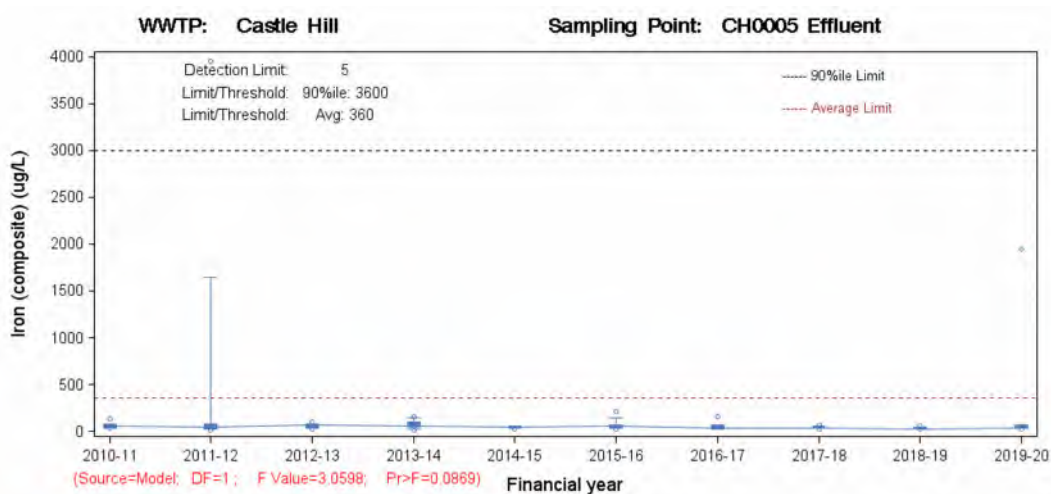




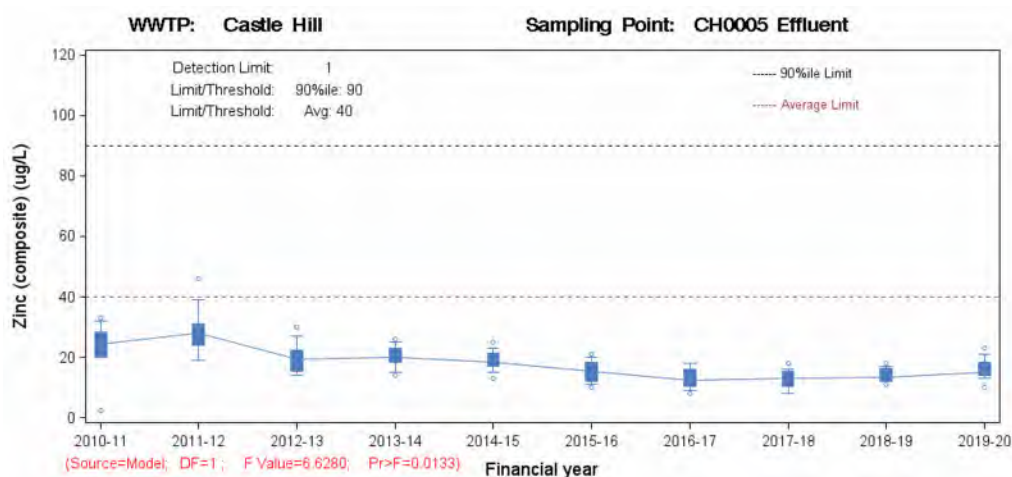
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.



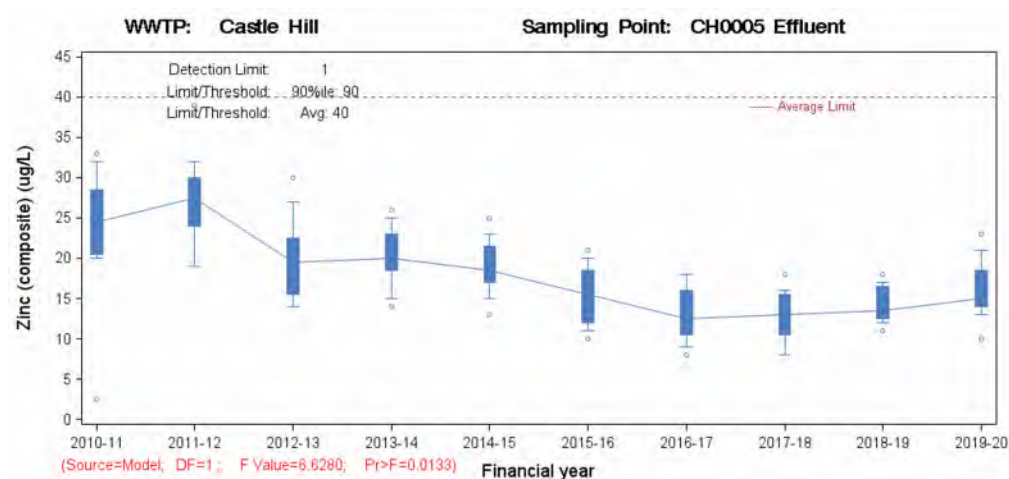
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.



Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

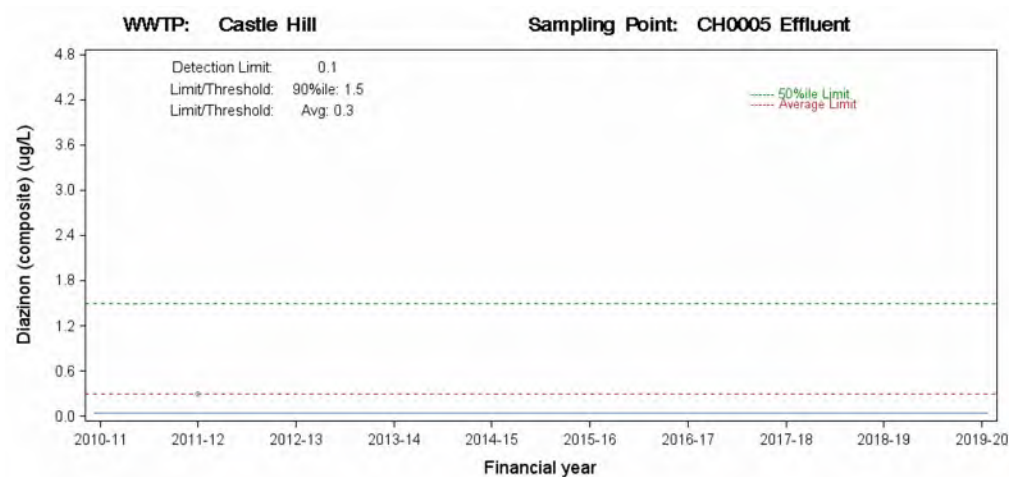


Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

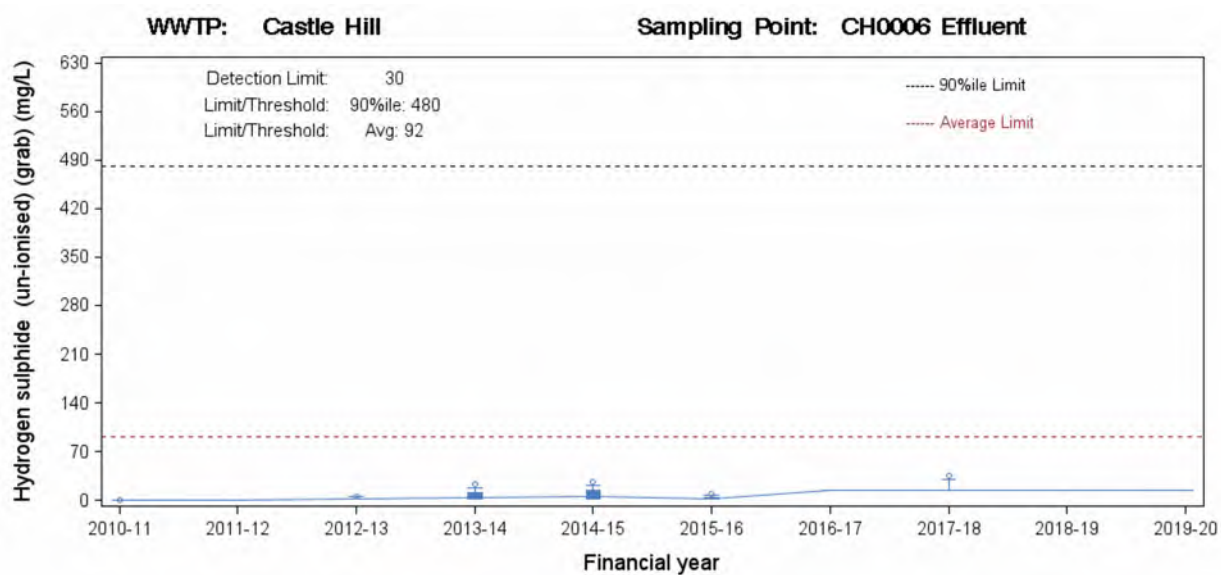


Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

Discharge quality: Other chemicals and organics (including pesticides)

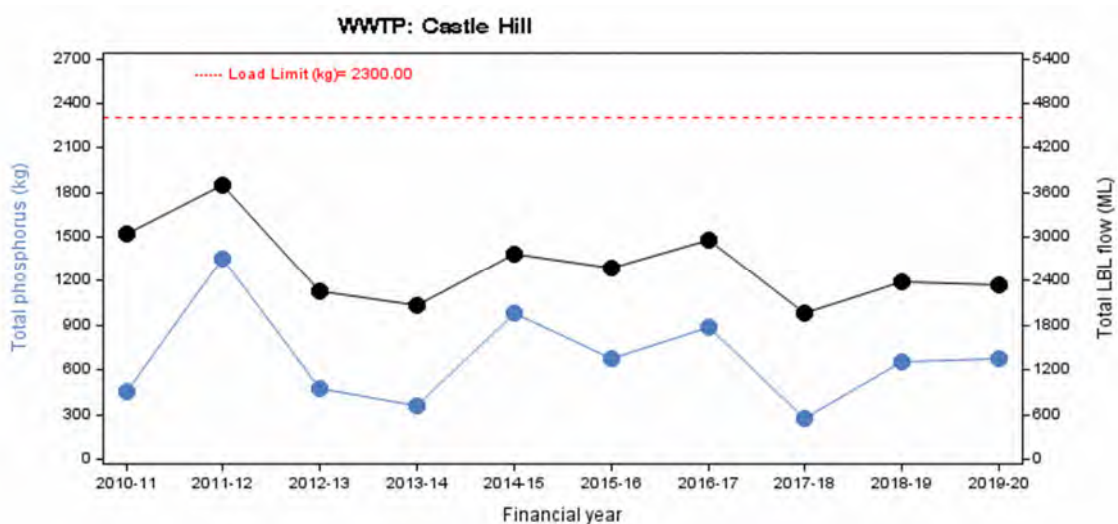
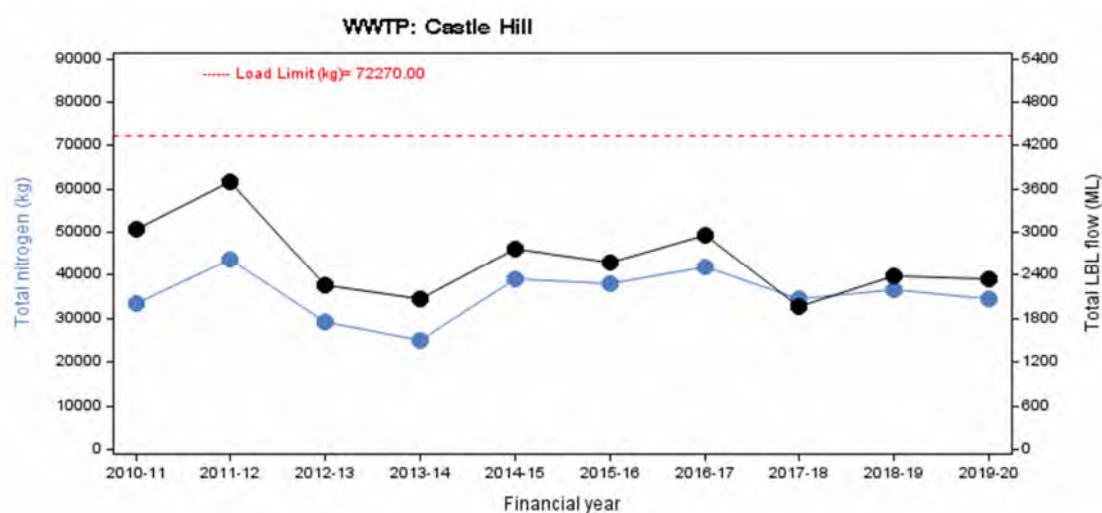


Note: Statistical test was not conducted because >90% of results were below the detection limit.

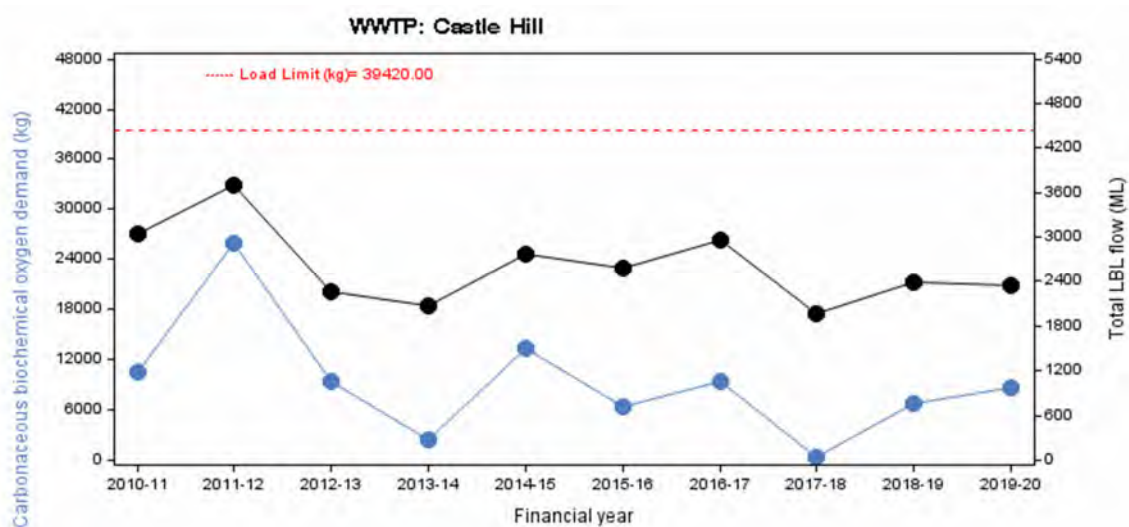


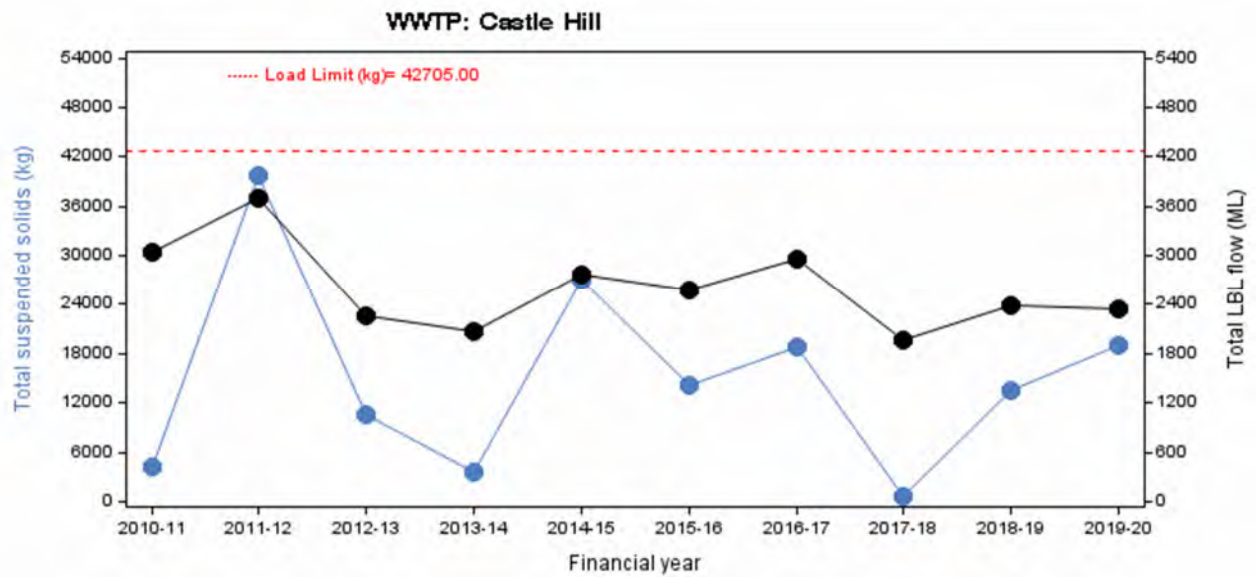
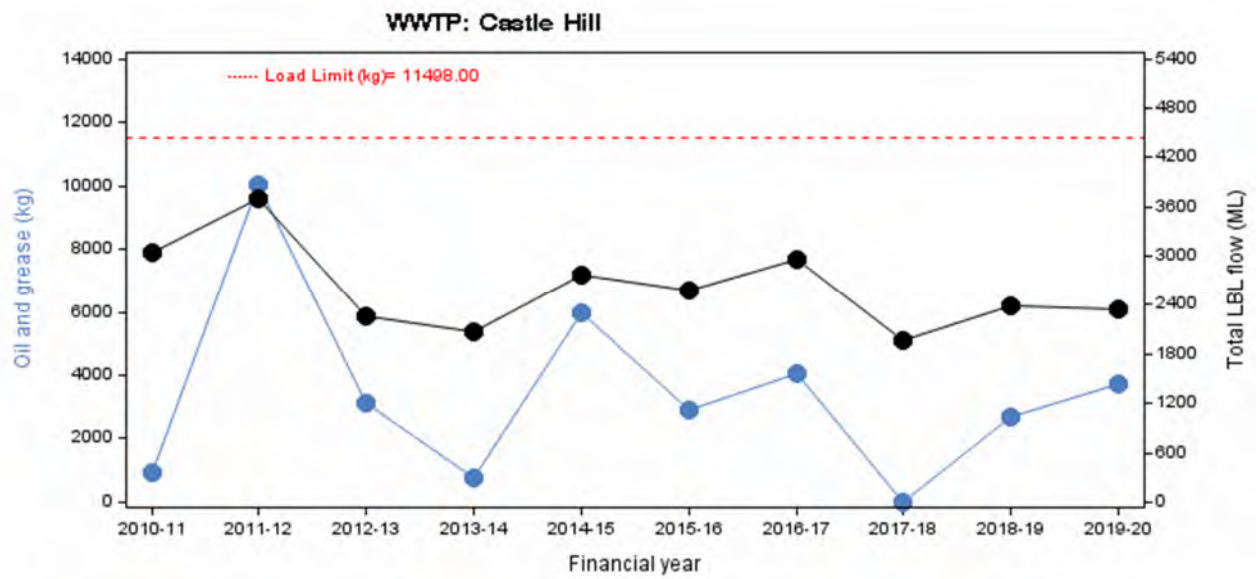
Note: 2019-20 data was compared with previous three years data (2016-2019) due to lab method change in 2016-17. Statistical test was not conducted because >90% of results were below the detection limit.

Discharge load: Nutrients



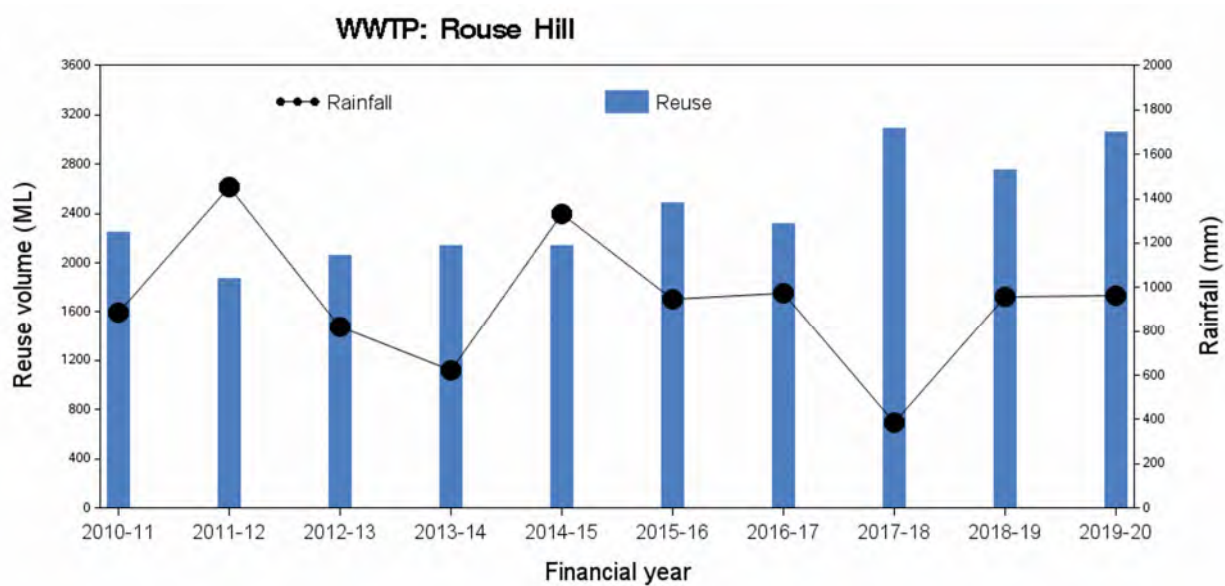
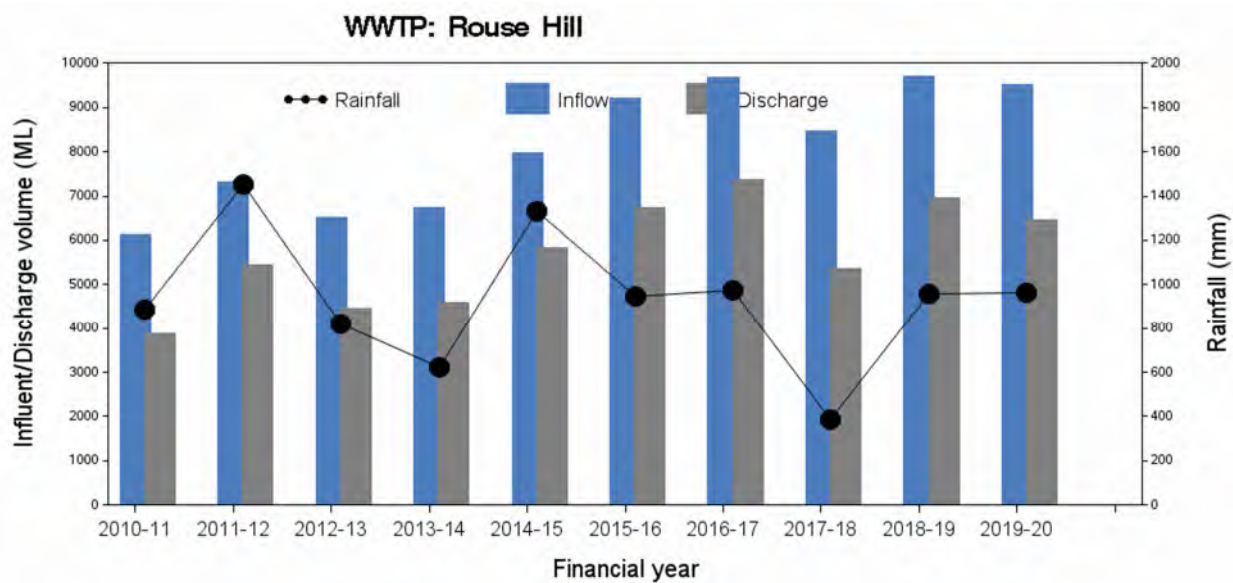
Discharge load: Major conventional analytes



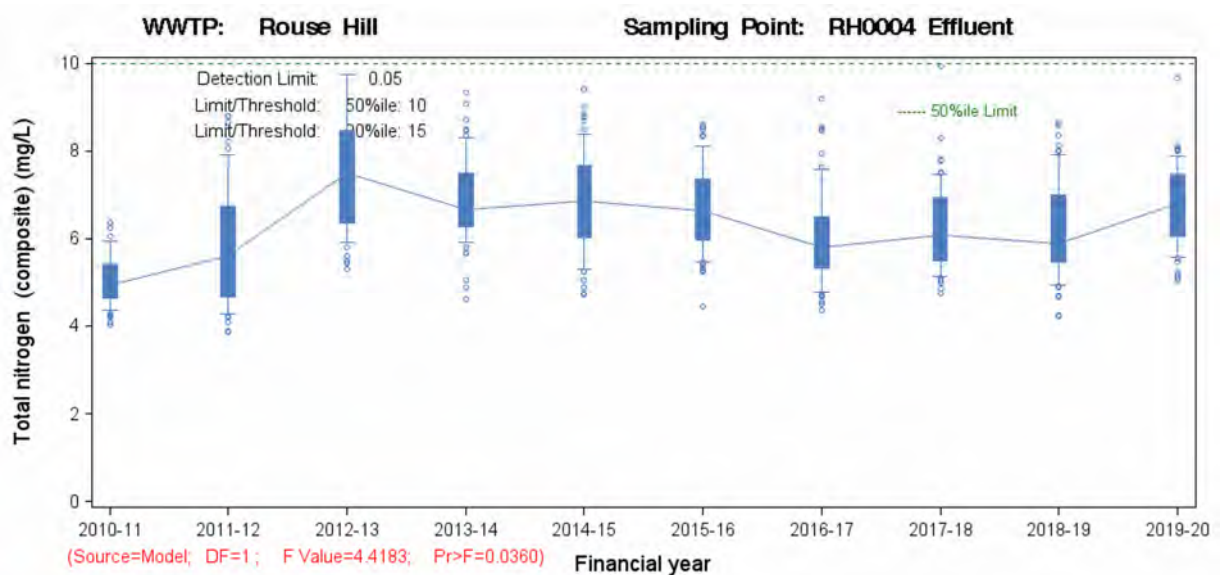
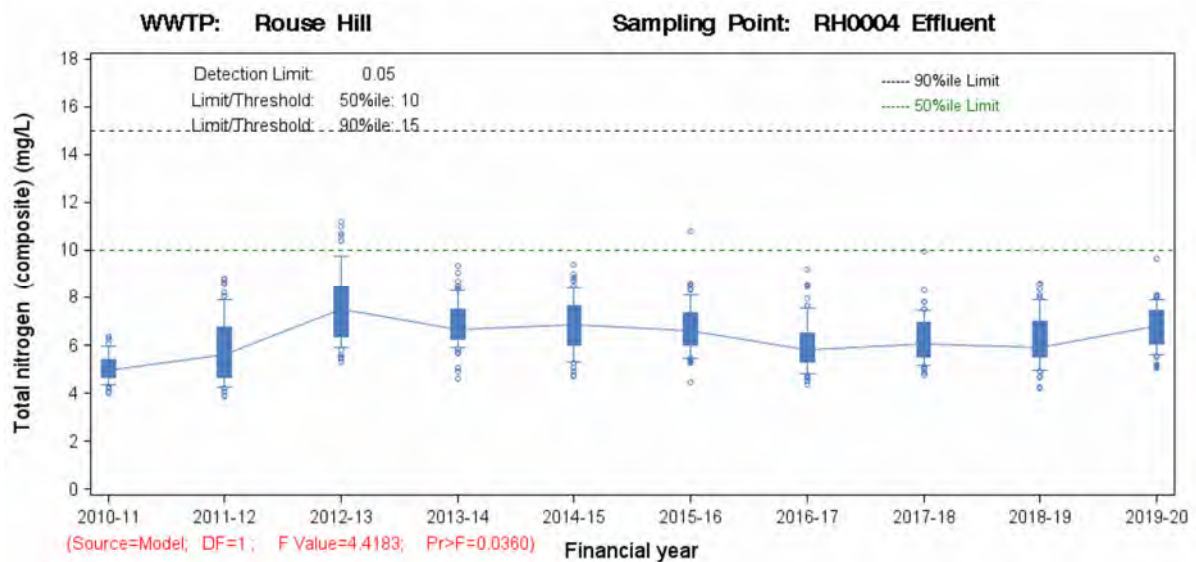
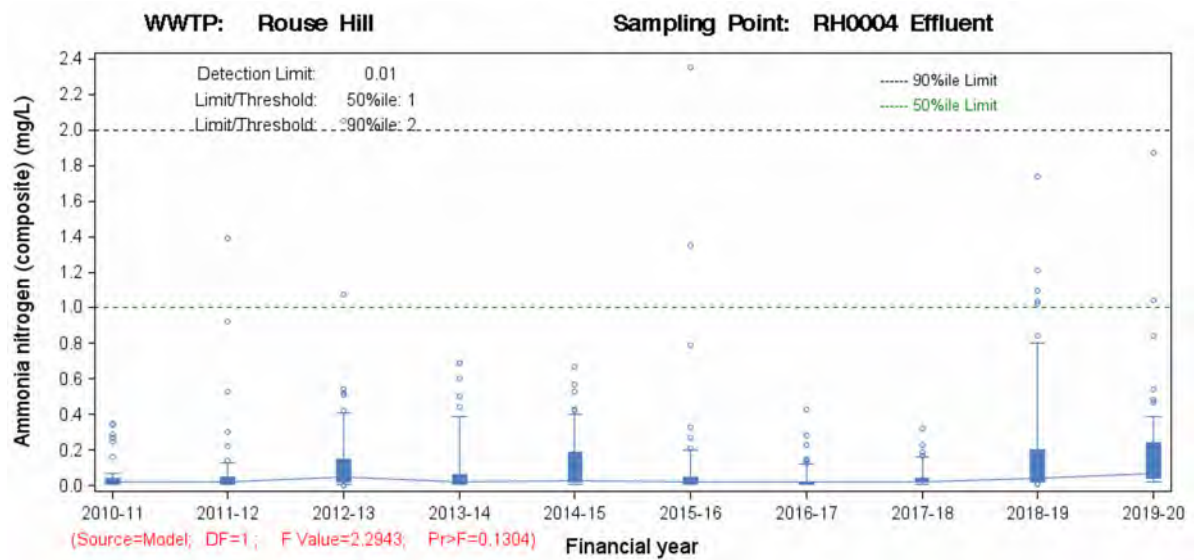


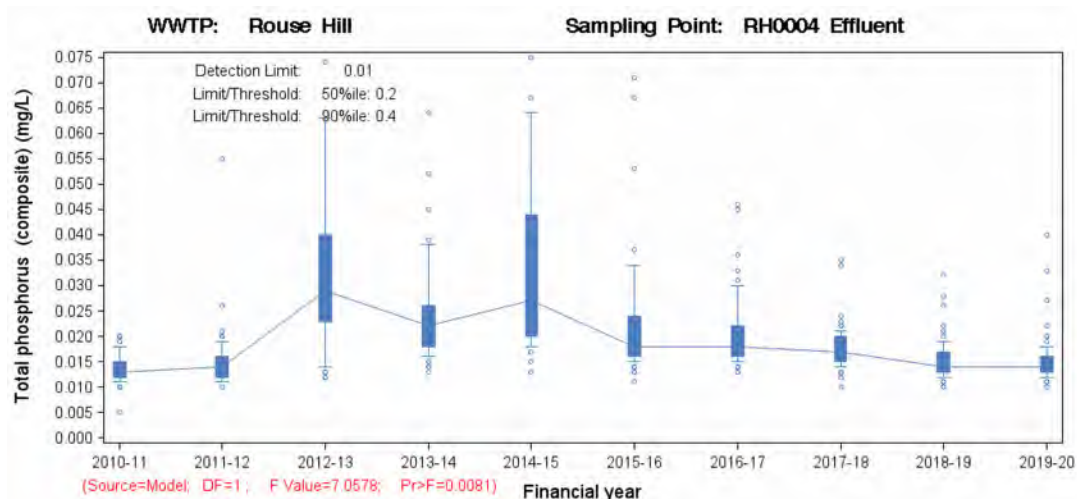
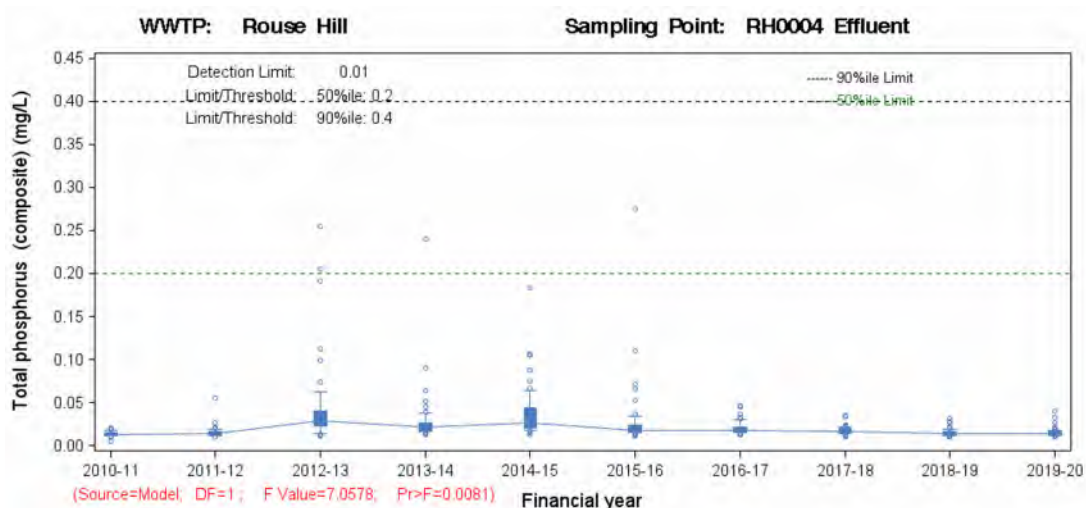
Rouse Hill WWTP

Discharge volume and rainfall

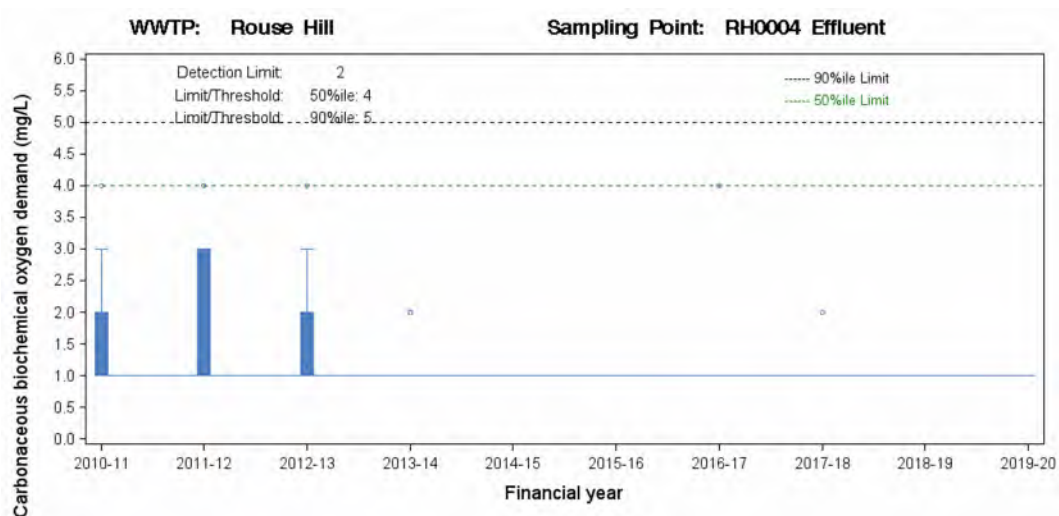


Discharge quality: Nutrients (RH0004 Effluent)

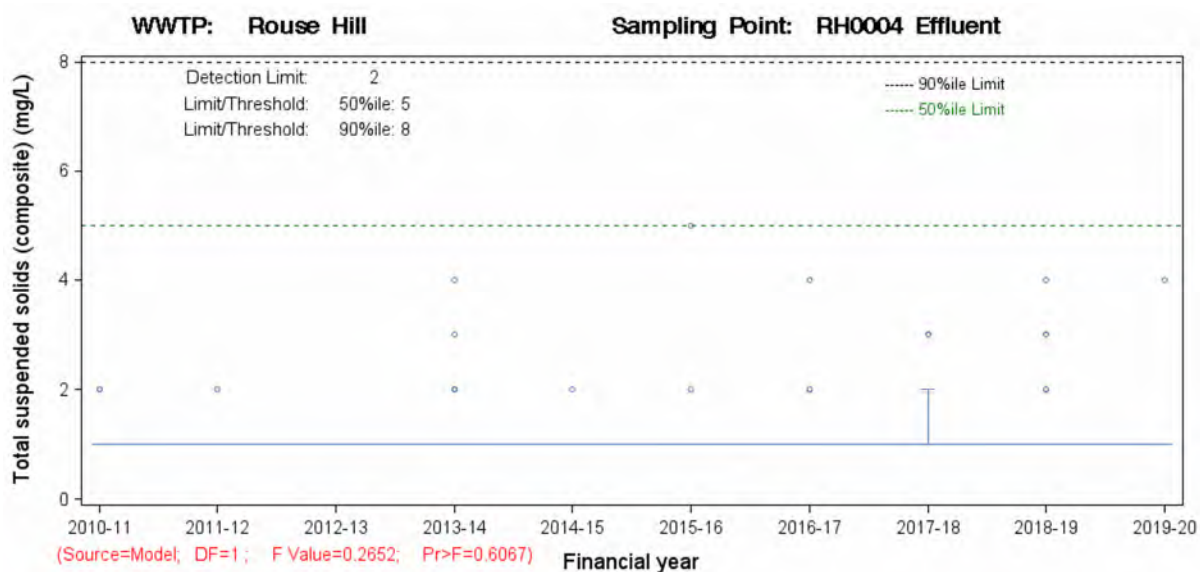
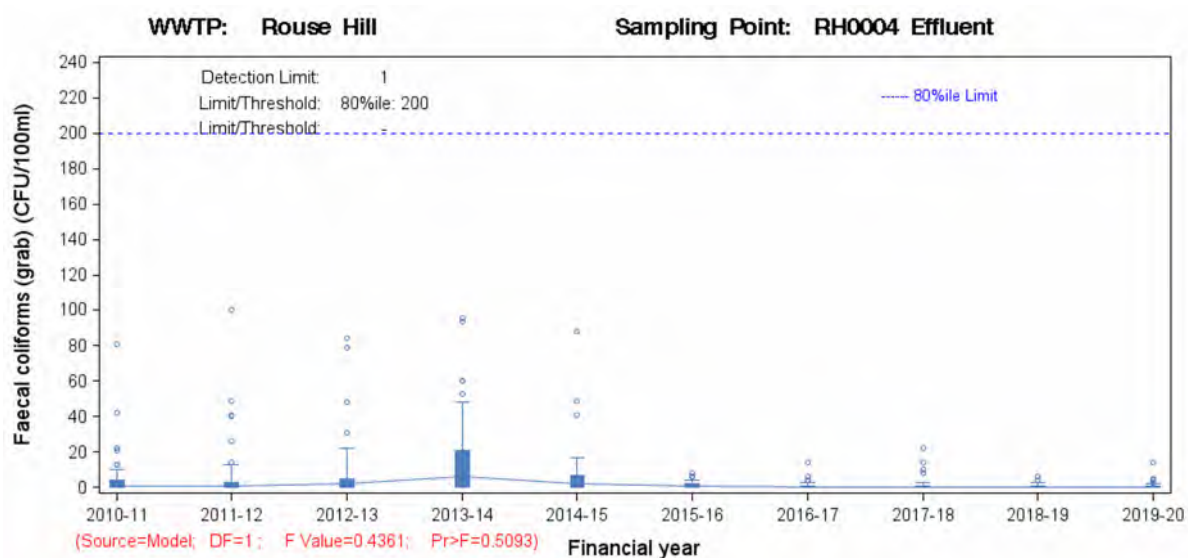
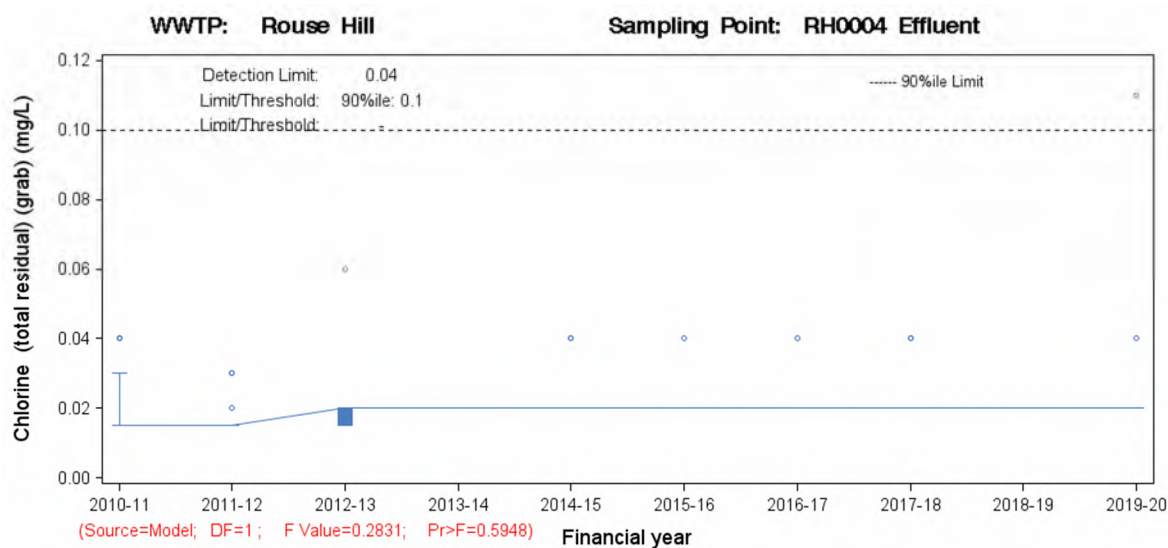




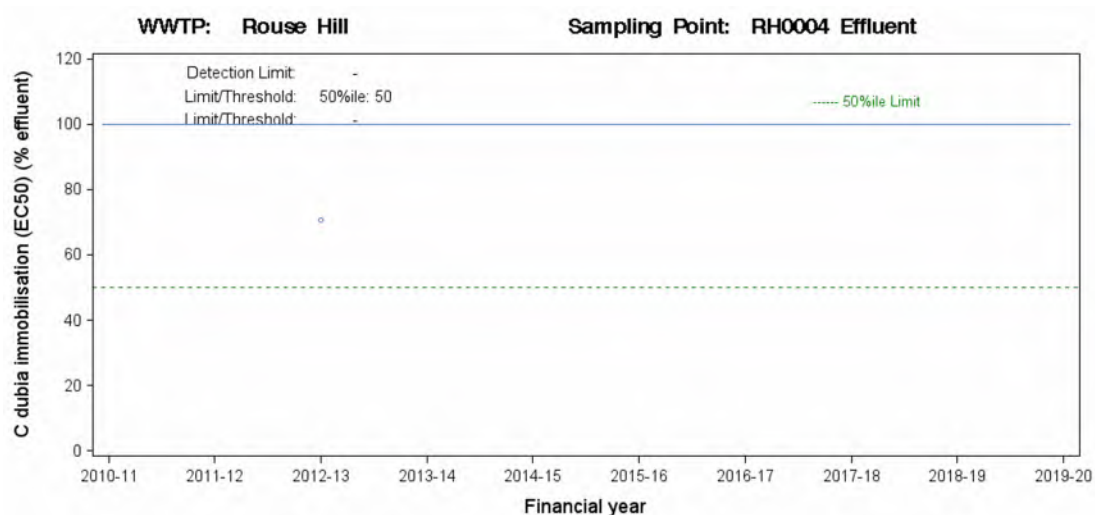
Discharge quality: Major conventional analytes (RH0004 Effluent)



Note: 2019-20 data was compared with previous five years data (2014-2019) due to lab method change in 2014-15. Statistical test was not conducted because >90% of results were below the detection limit.

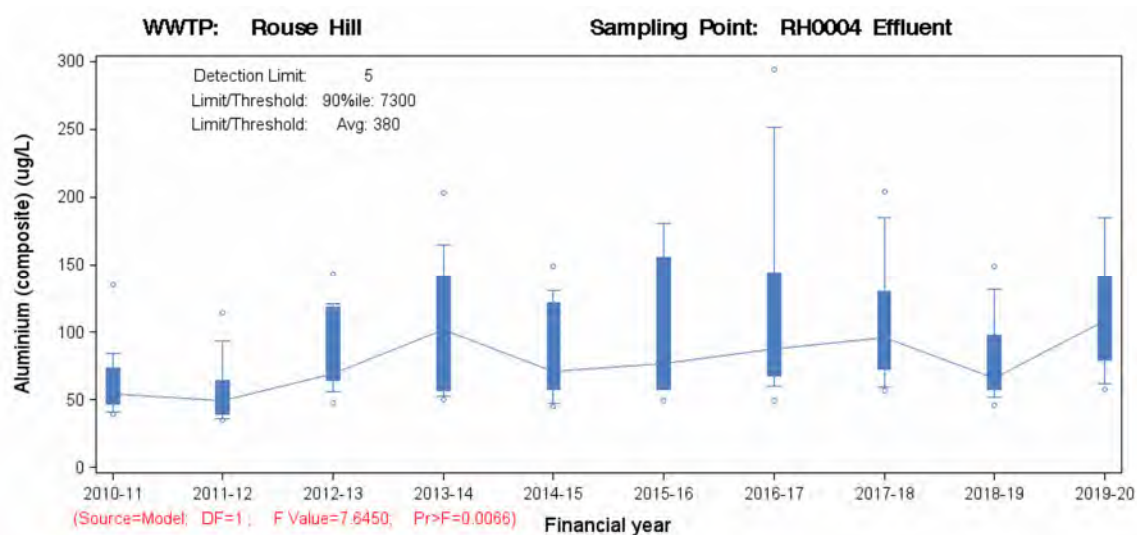
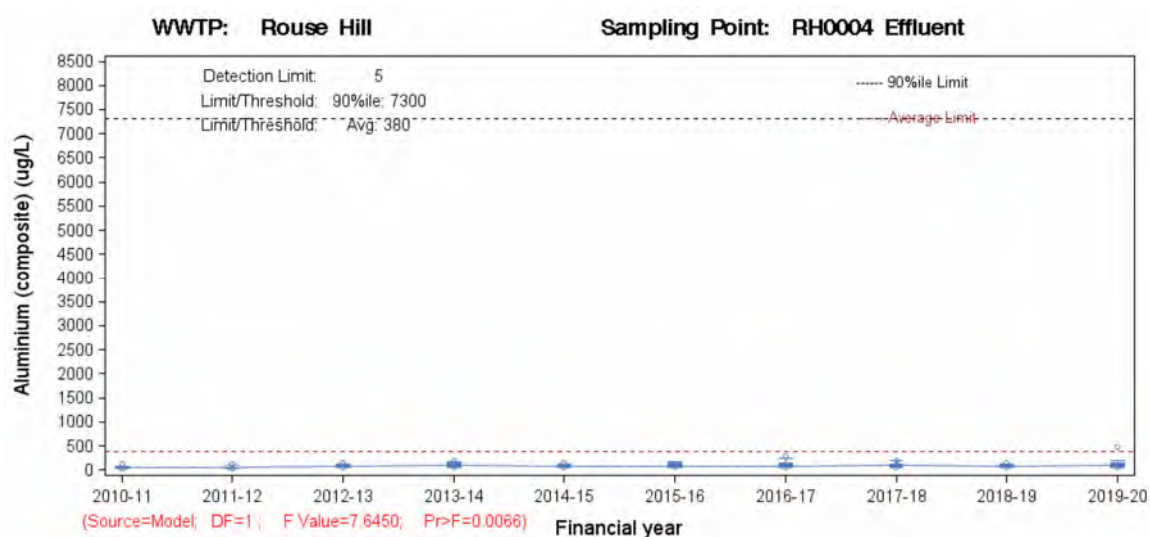


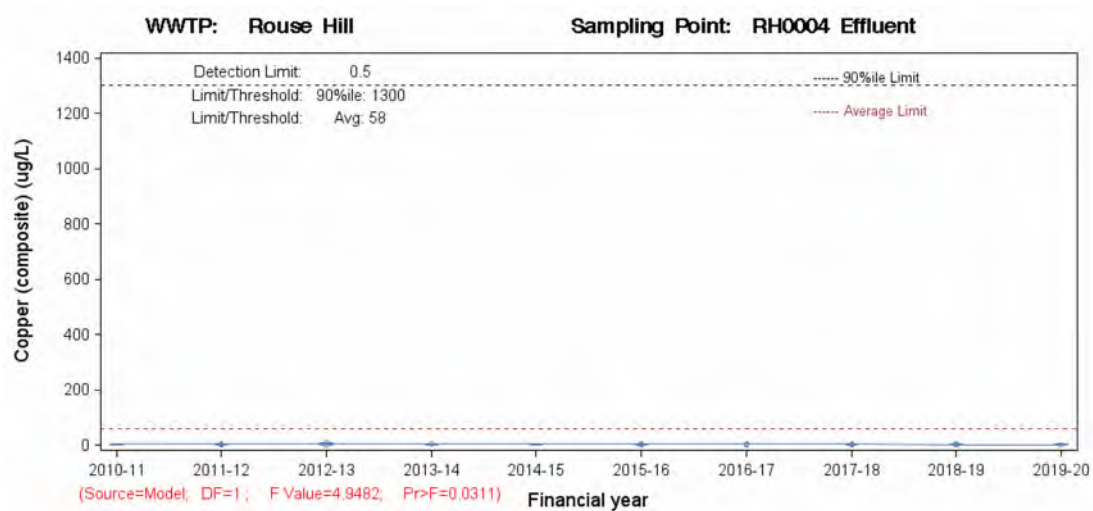
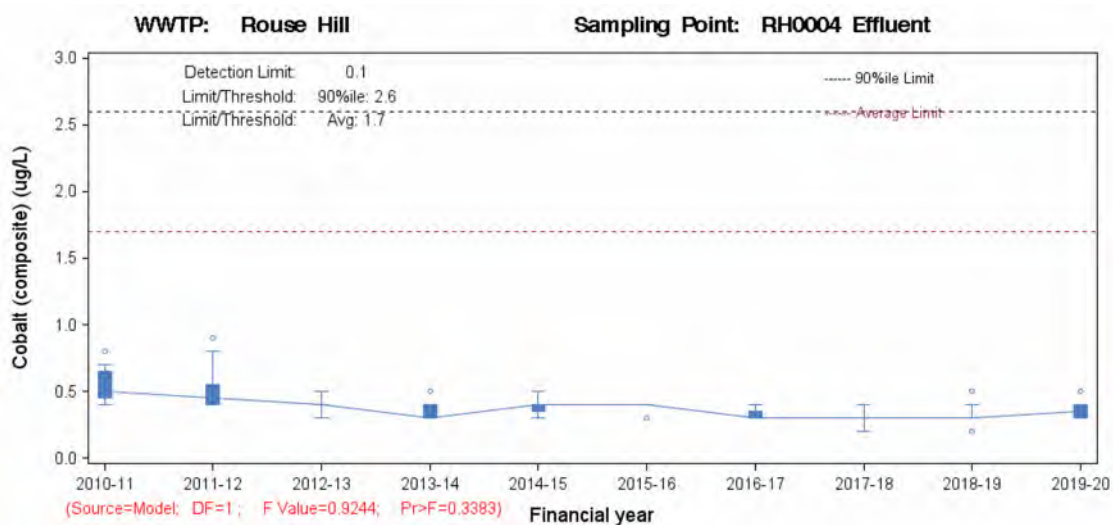
Discharge quality: Toxicity (RH0004 Effluent)



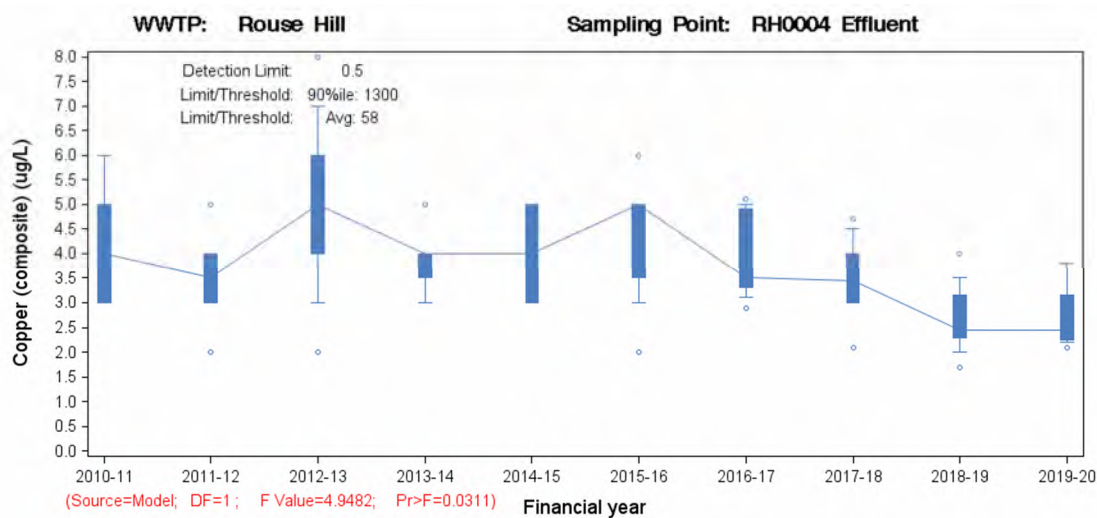
Note: Statistical test was not conducted because >90% of results were recorded at 100% survival for *Ceriodaphnia dubia*.

Discharge quality: Trace metals (RH0004 Effluent)

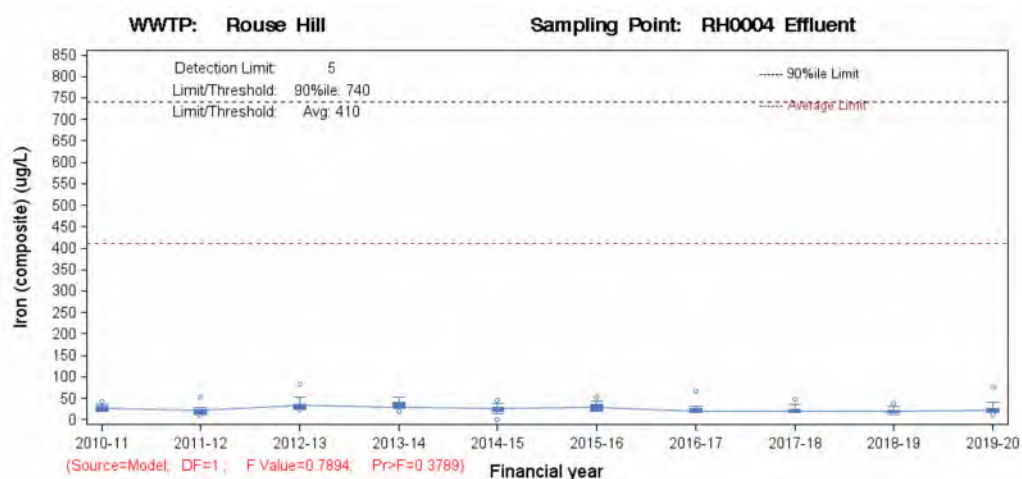




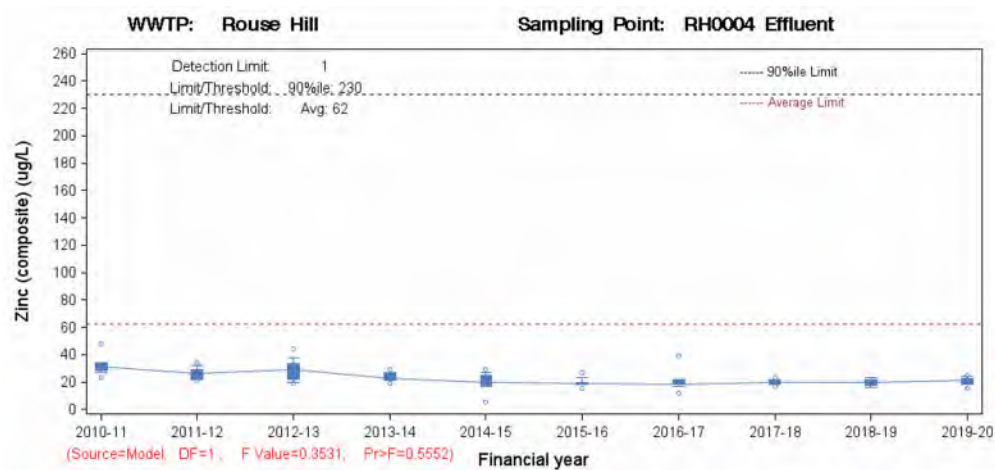
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.



Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

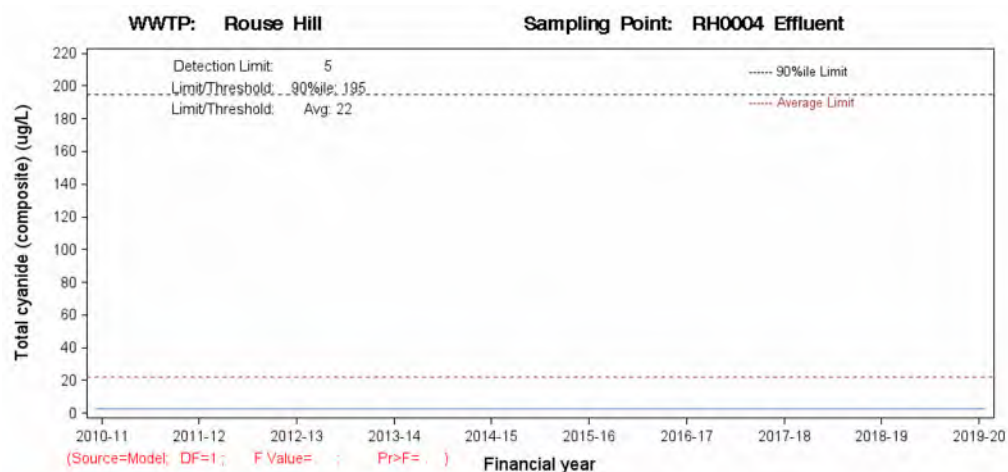


Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.



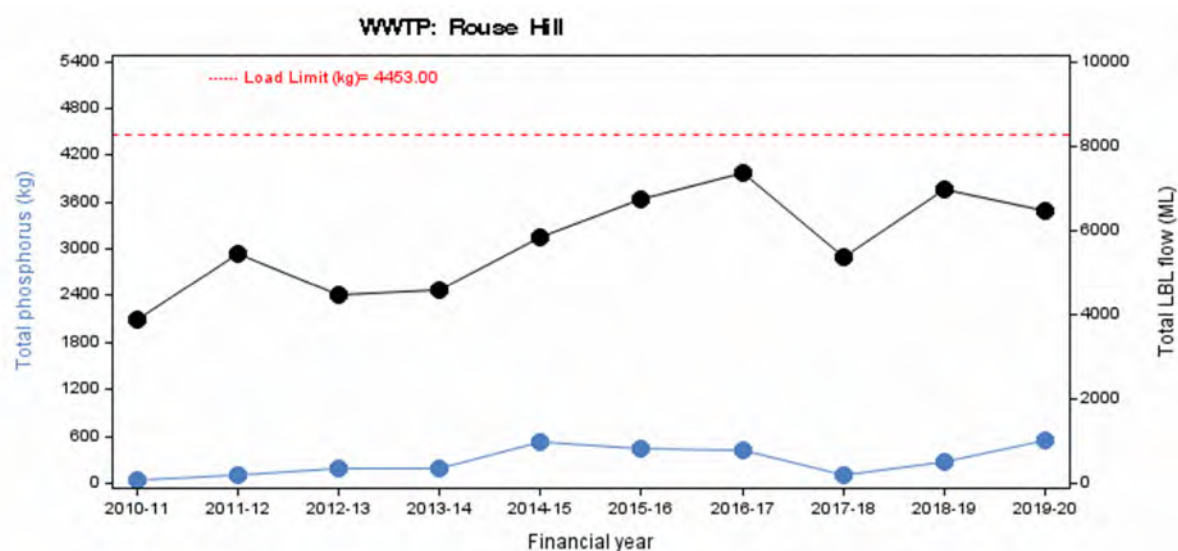
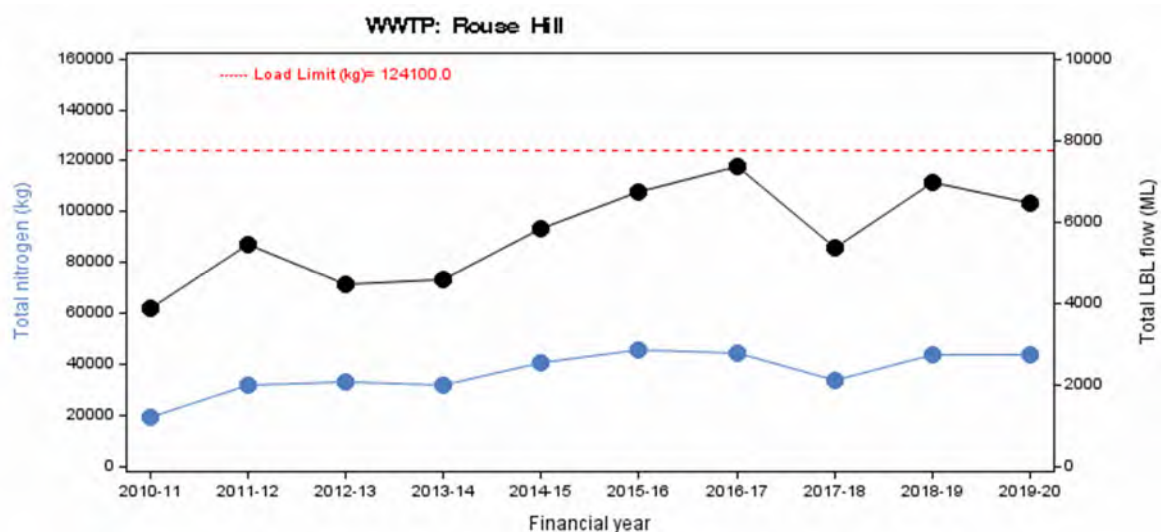
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

Discharge quality: Other chemicals and organics (including pesticides) (RH0004 Effluent)

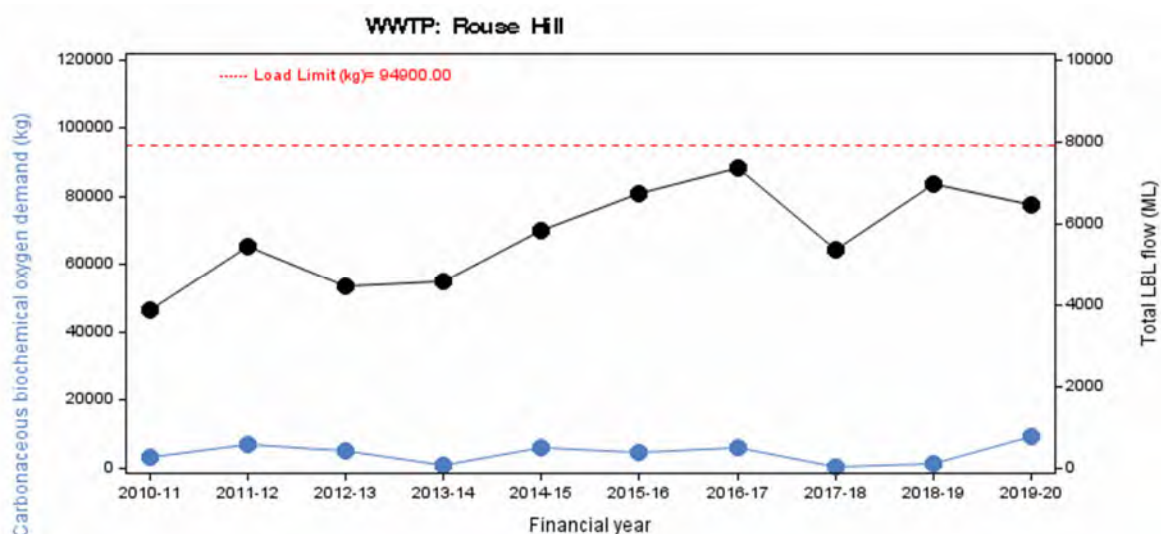


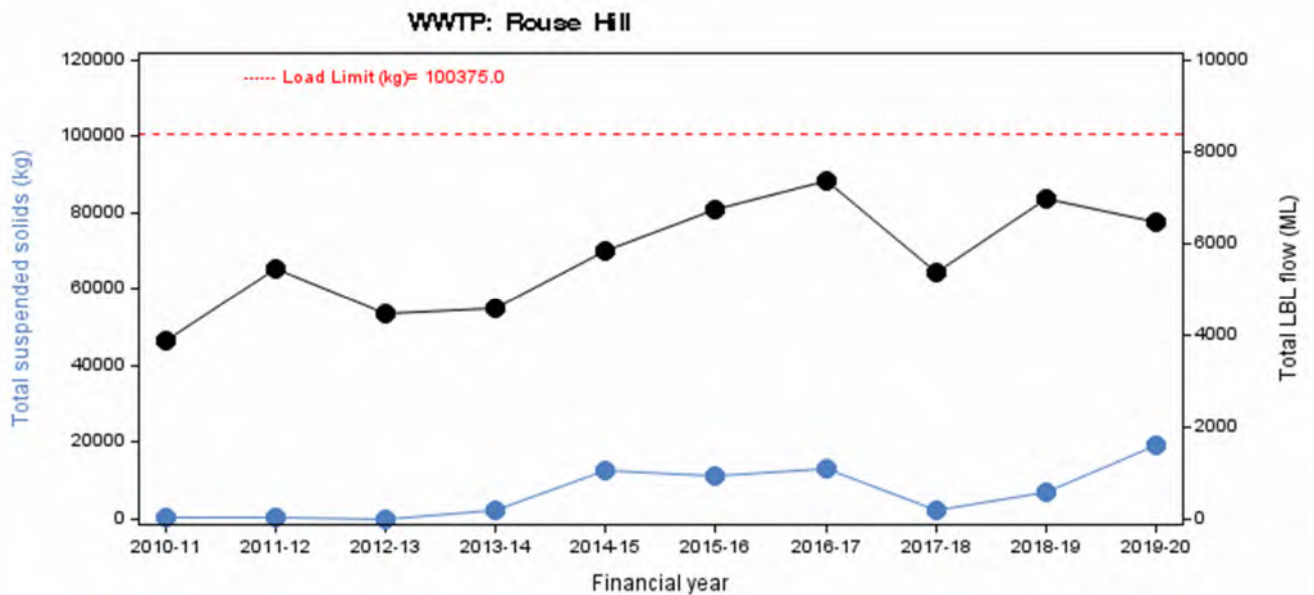
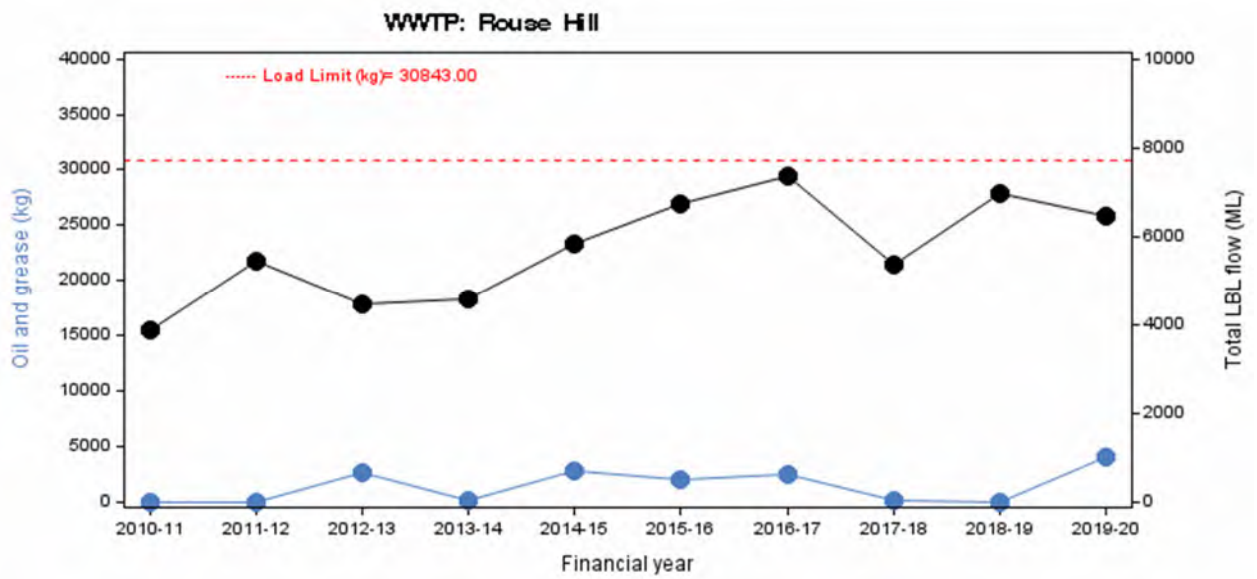
Note: Statistical test was not conducted because >90% of results were below the detection limit.

Discharge load: Nutrients



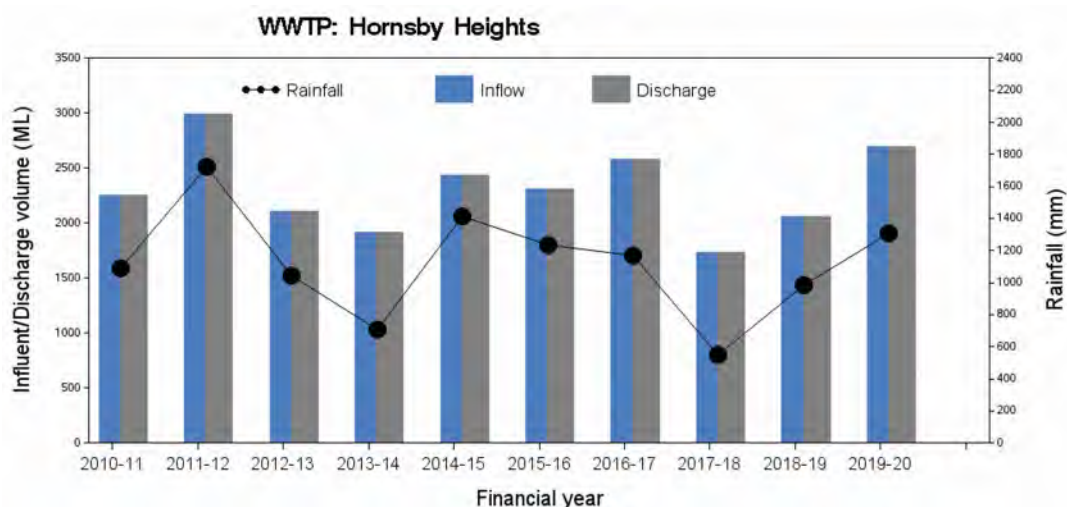
Discharge load: Major conventional analytes



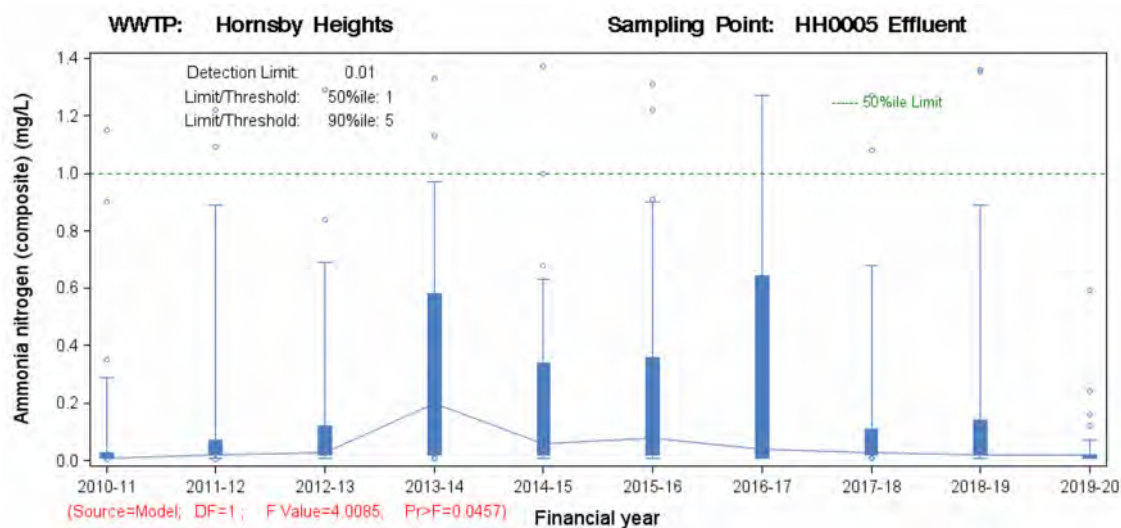
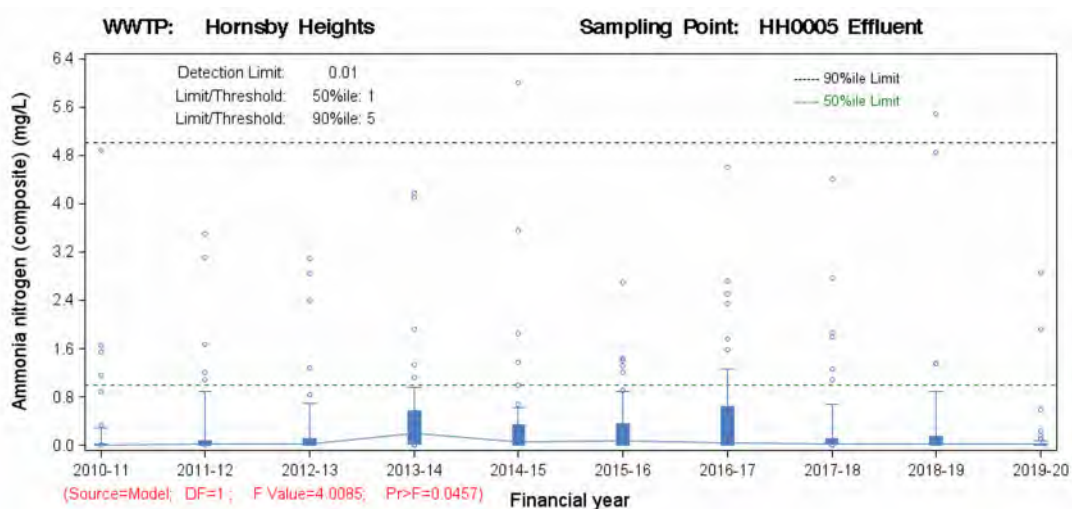


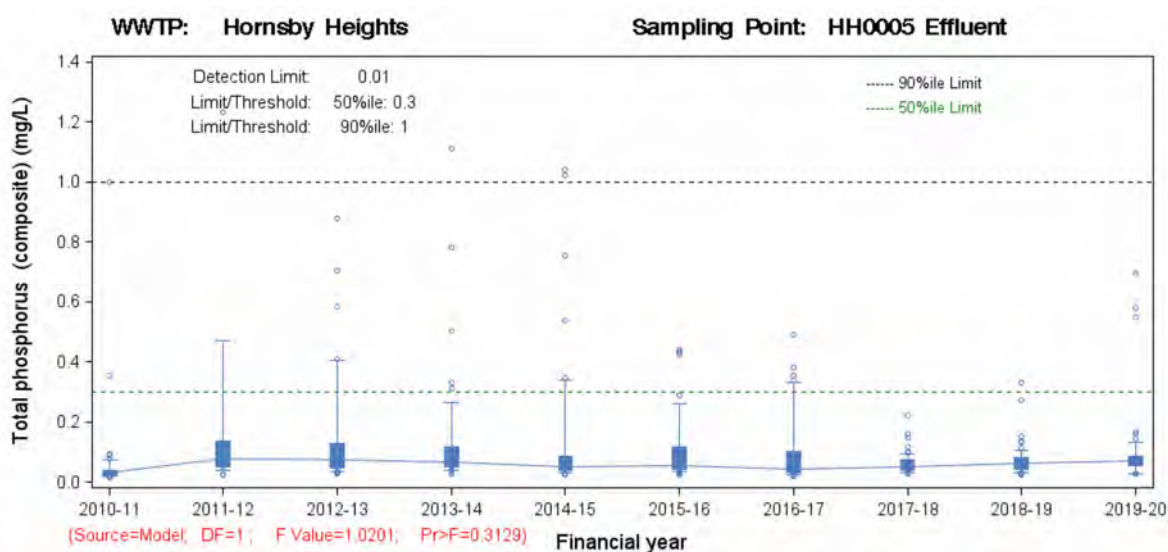
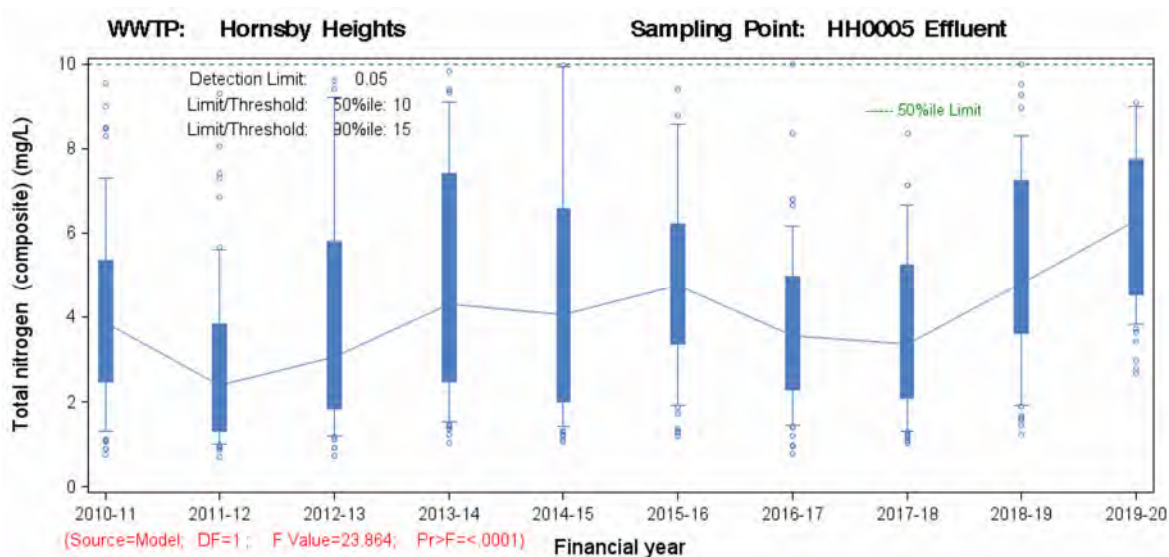
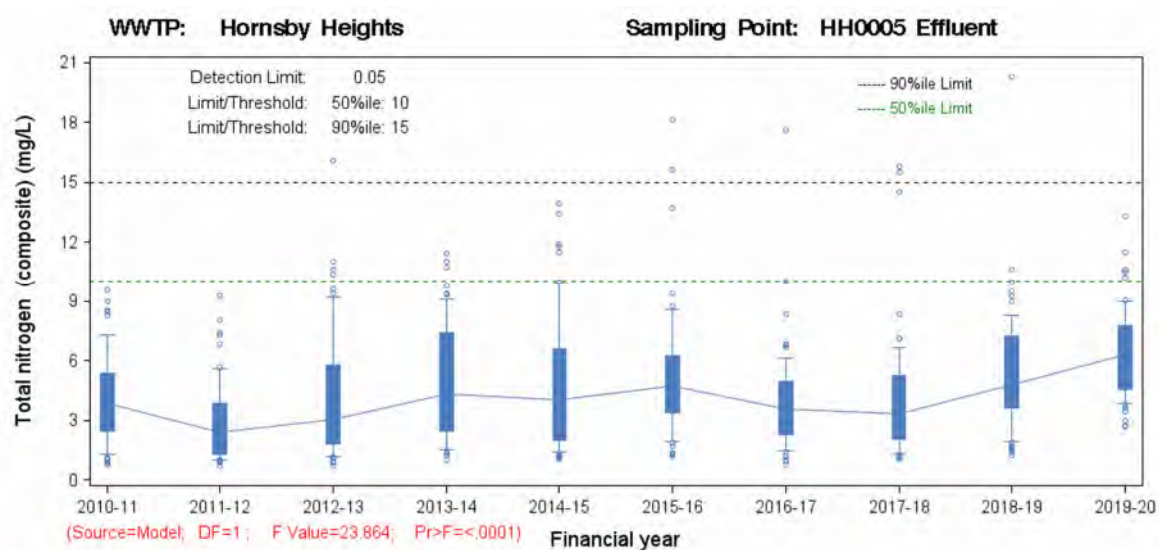
Hornsby Heights WWTP

Discharge volume and rainfall

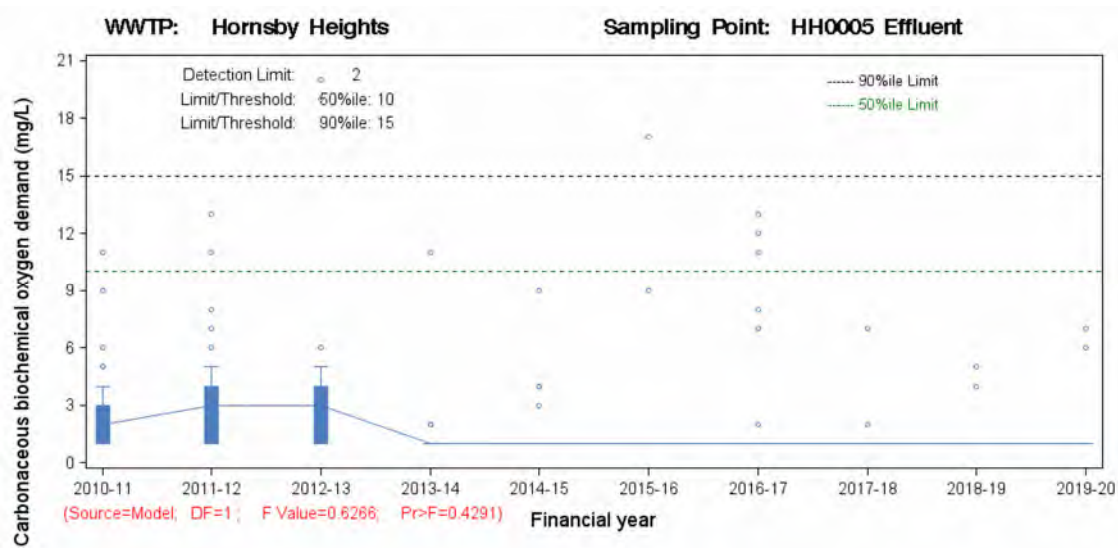


Discharge quality: Nutrients

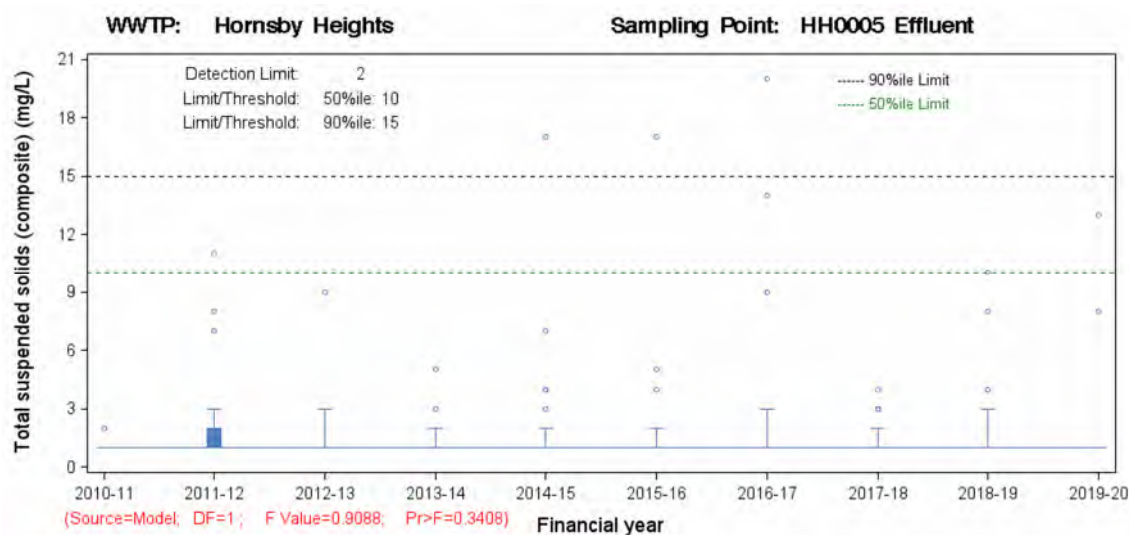
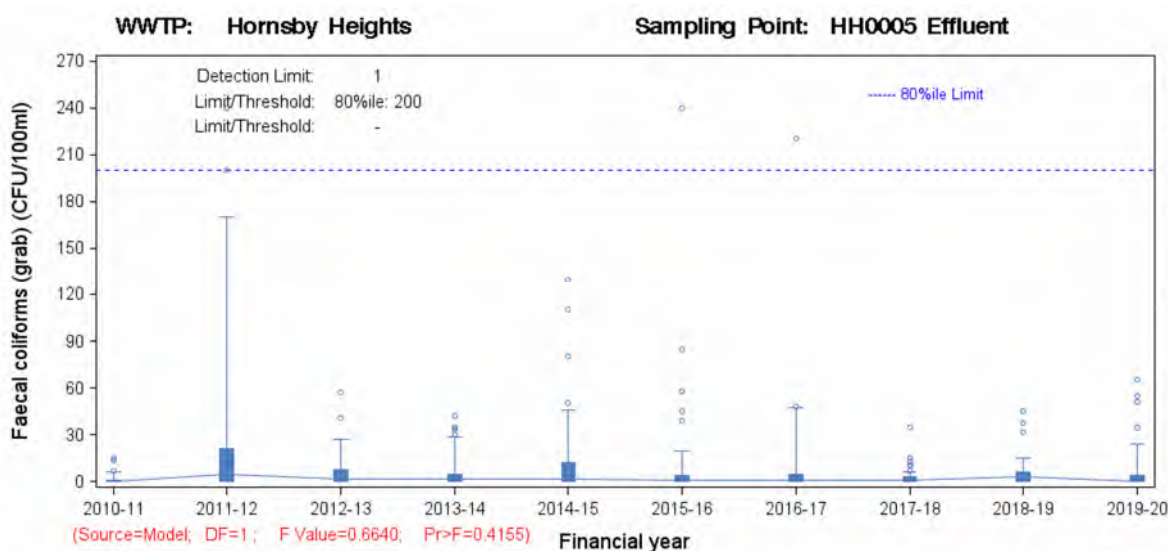




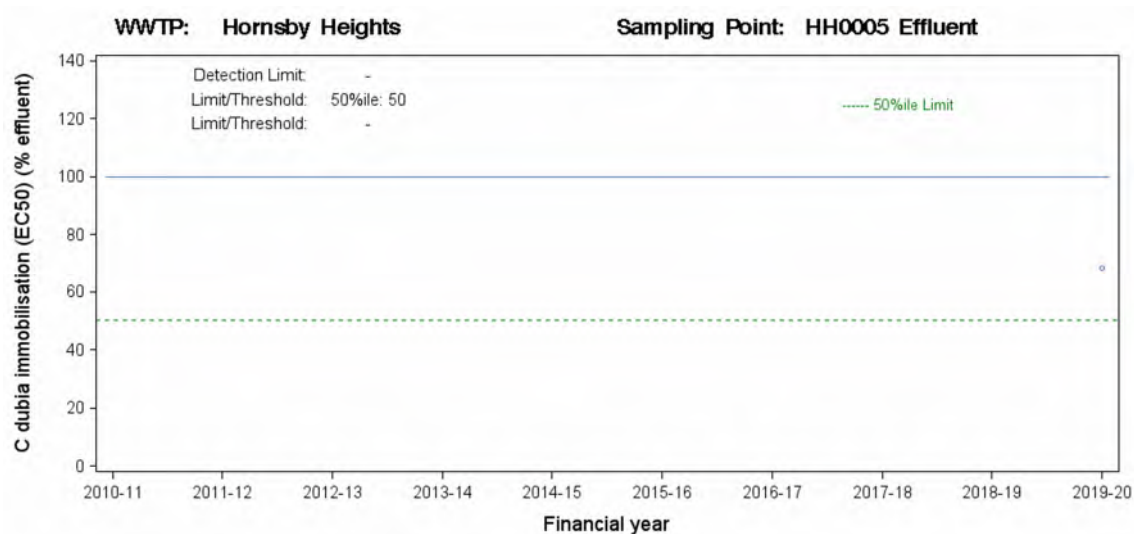
Discharge quality: Major conventional analytes



Note: Statistical test was based on 2019-20 data with previous five years data (2014-2019) due to lab method change in 2014-15.

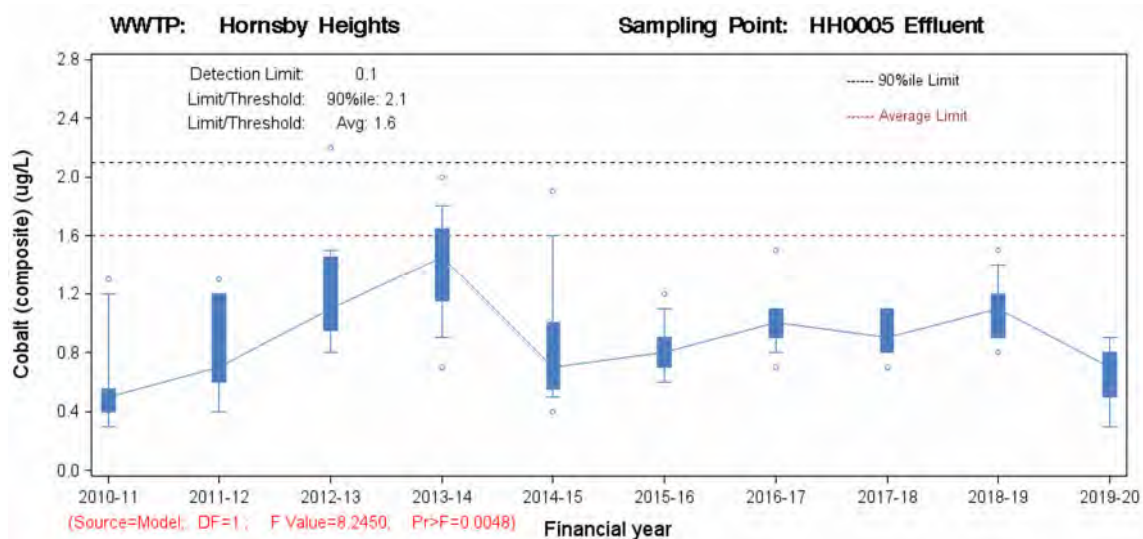
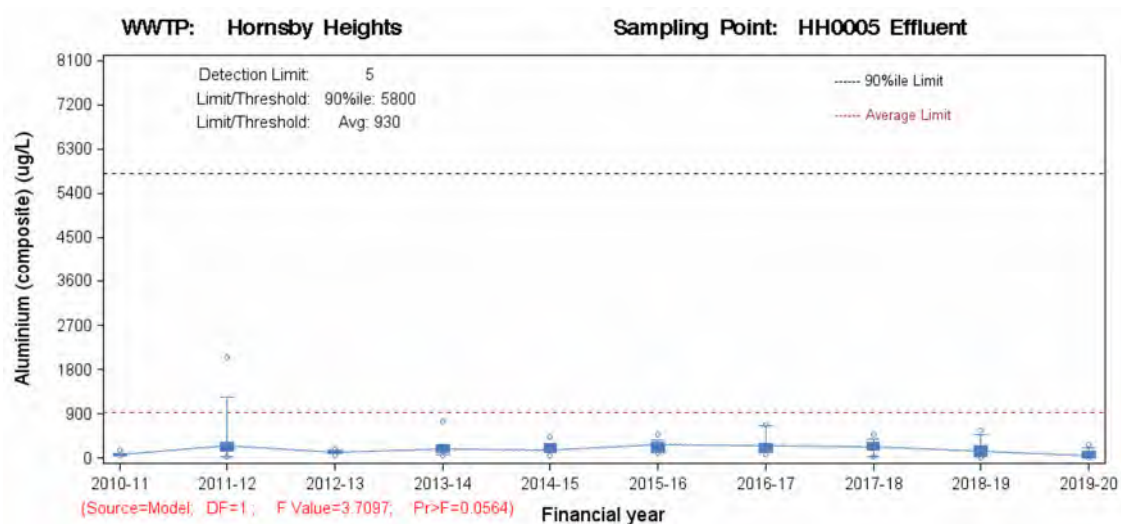


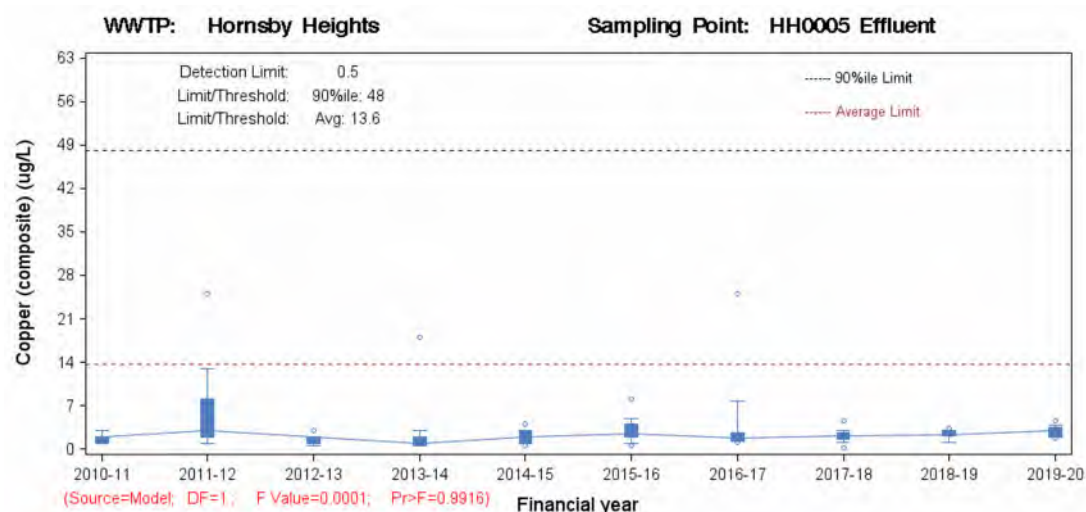
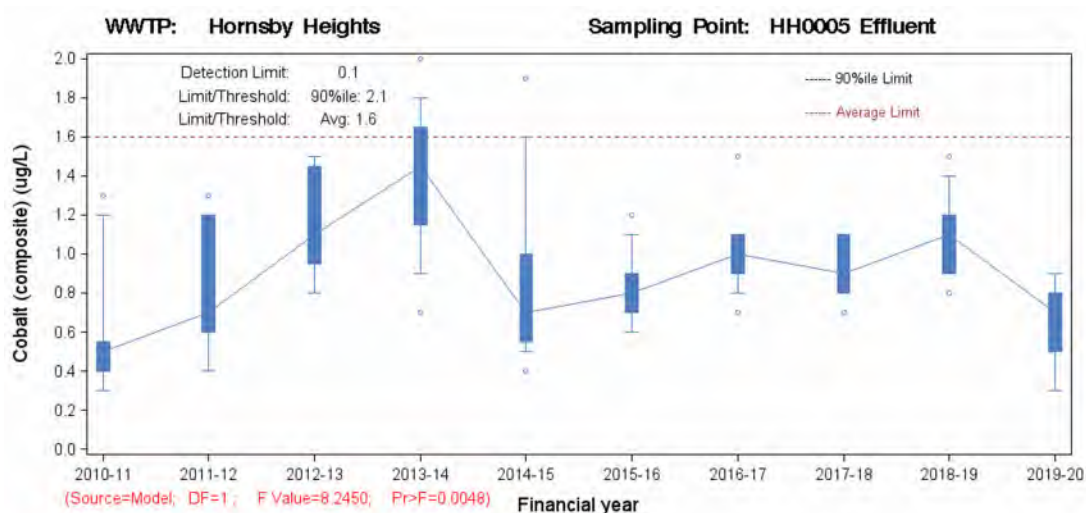
Discharge quality: Toxicity



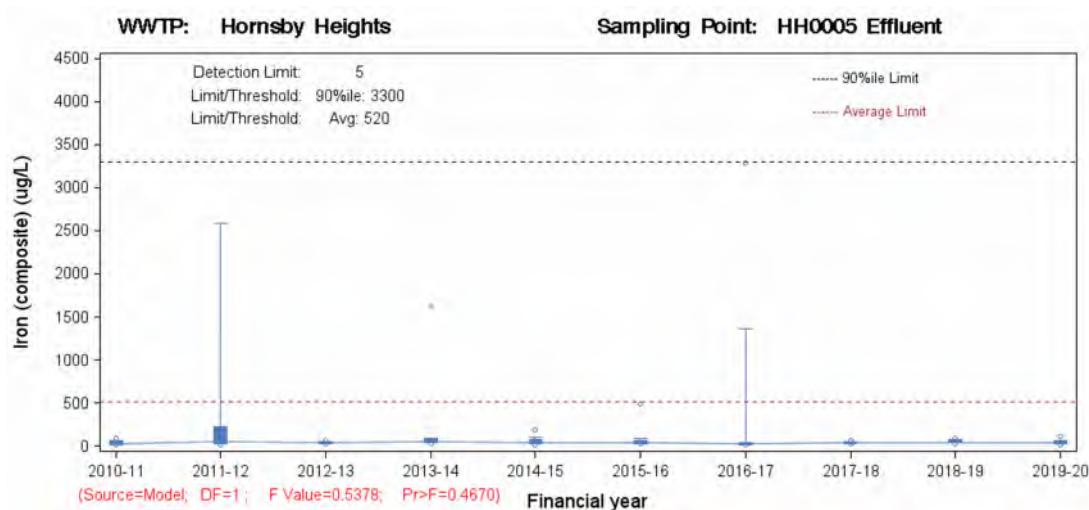
Note: Statistical test was not conducted because >90% of results were recorded at 100% survival for *Ceriodaphnia dubia*.

Discharge quality: Trace metals

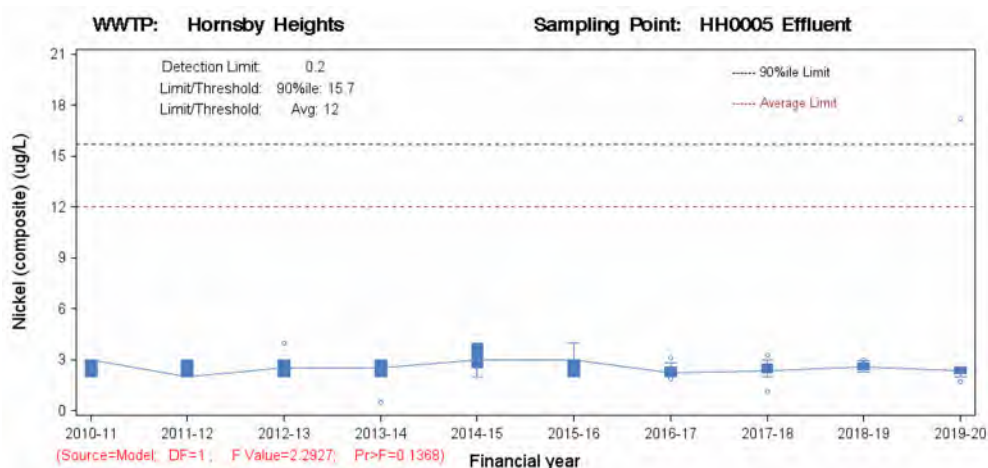




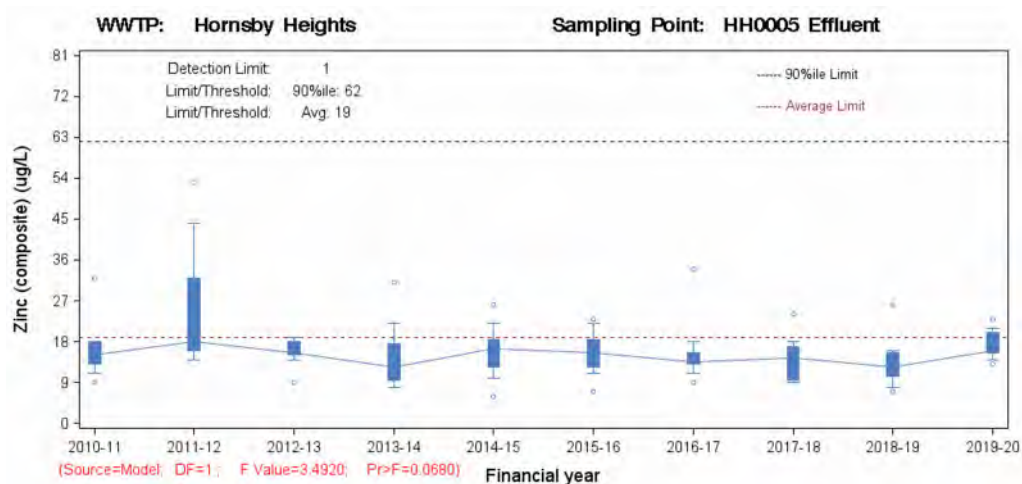
Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.



Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

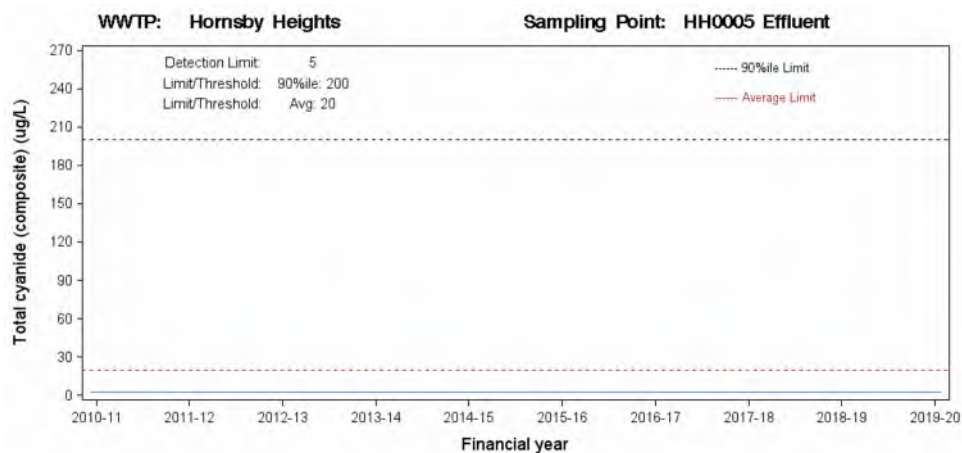


Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

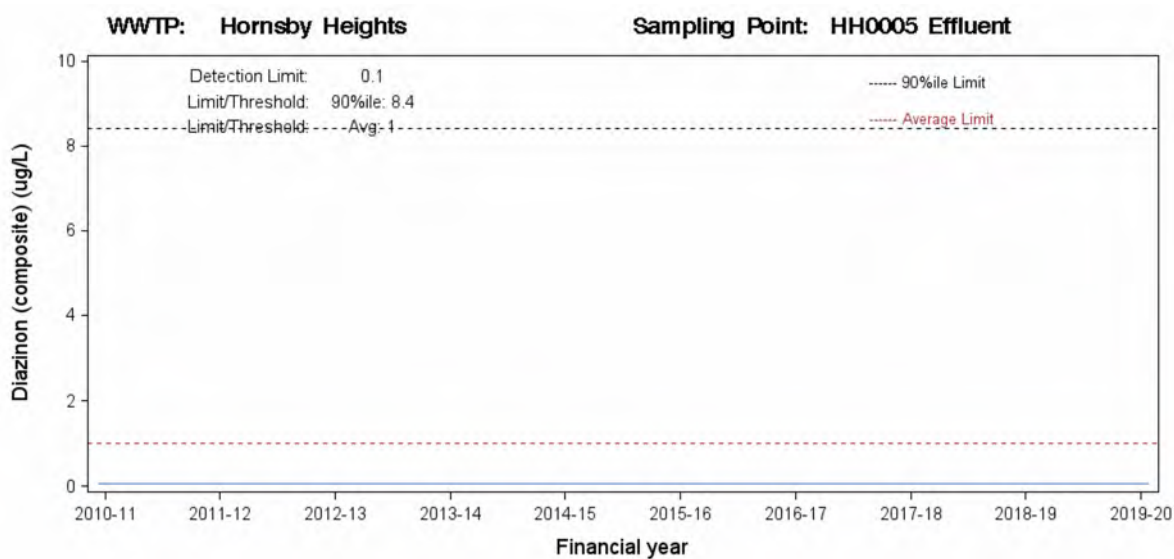


Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

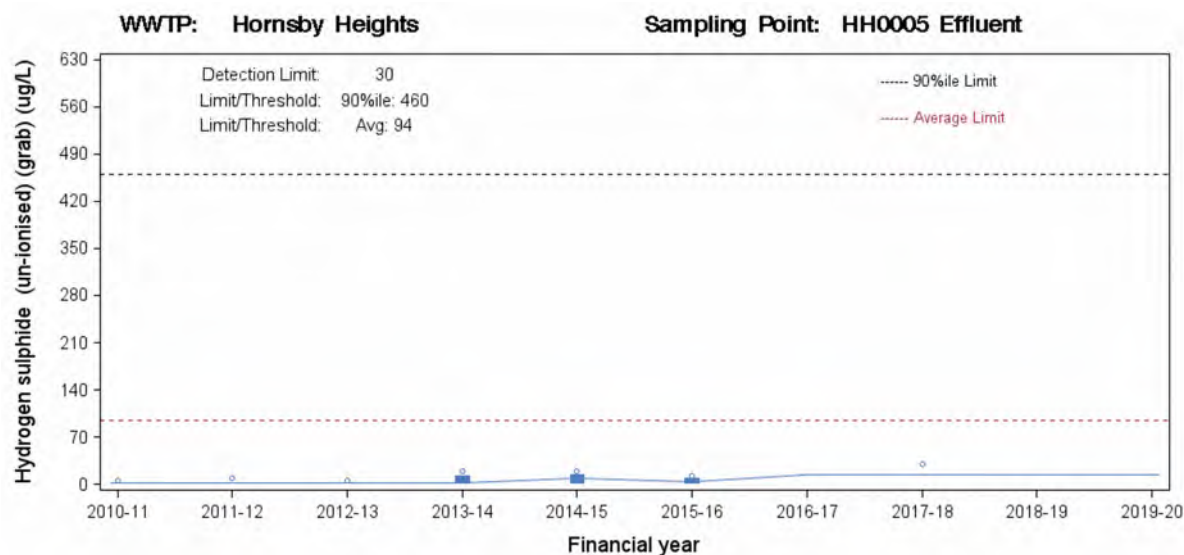
Discharge quality: Other chemicals and organics (including pesticides)



Note: Statistical test was not conducted because >90% of results were below the detection limit.

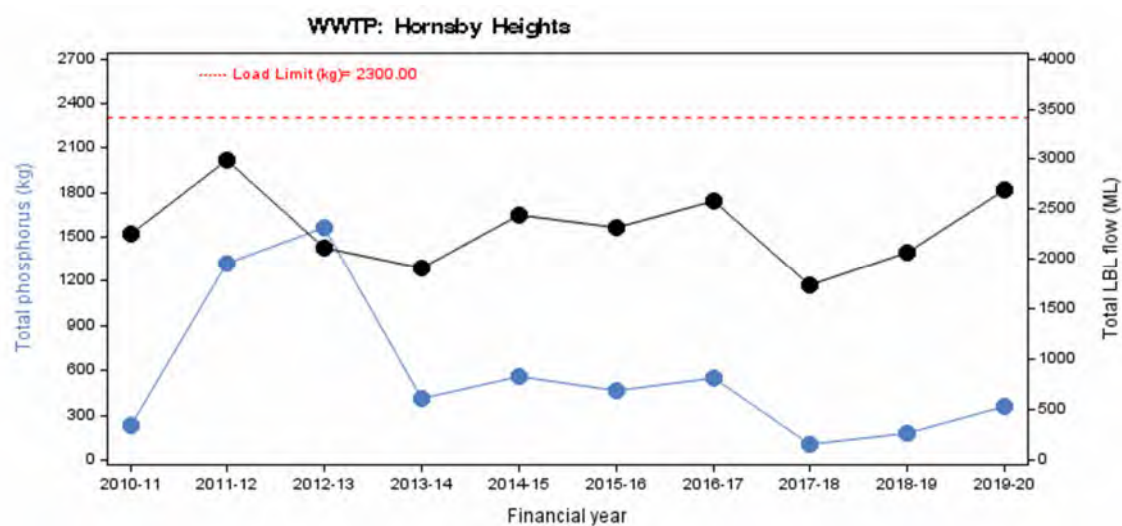
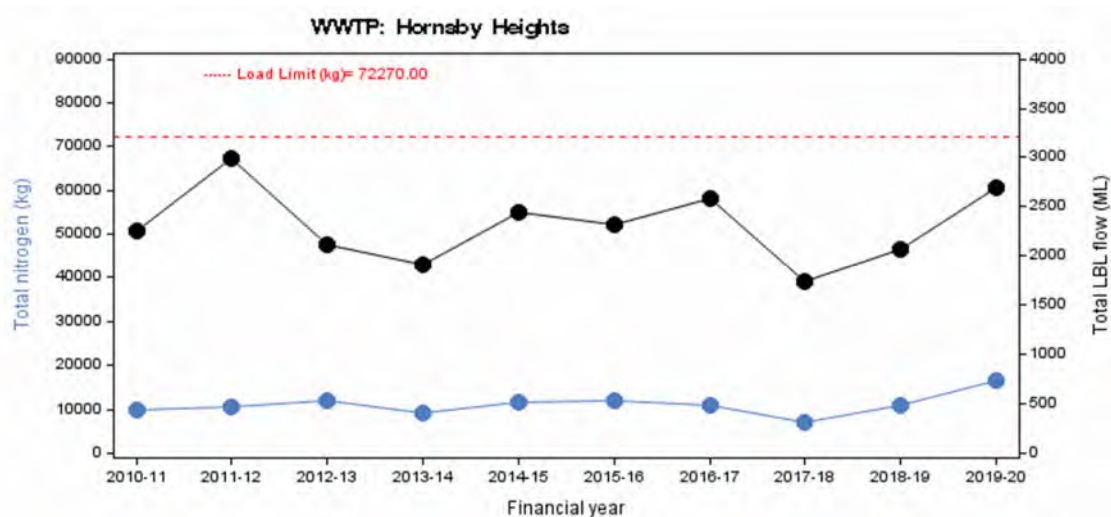


Note: Statistical test was not conducted because >90% of results were below the detection limit.

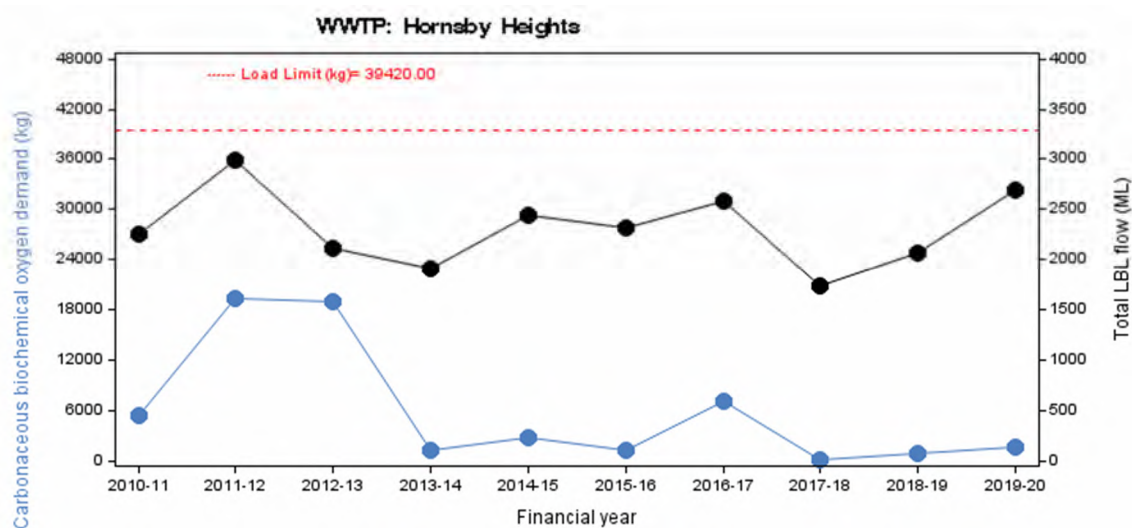


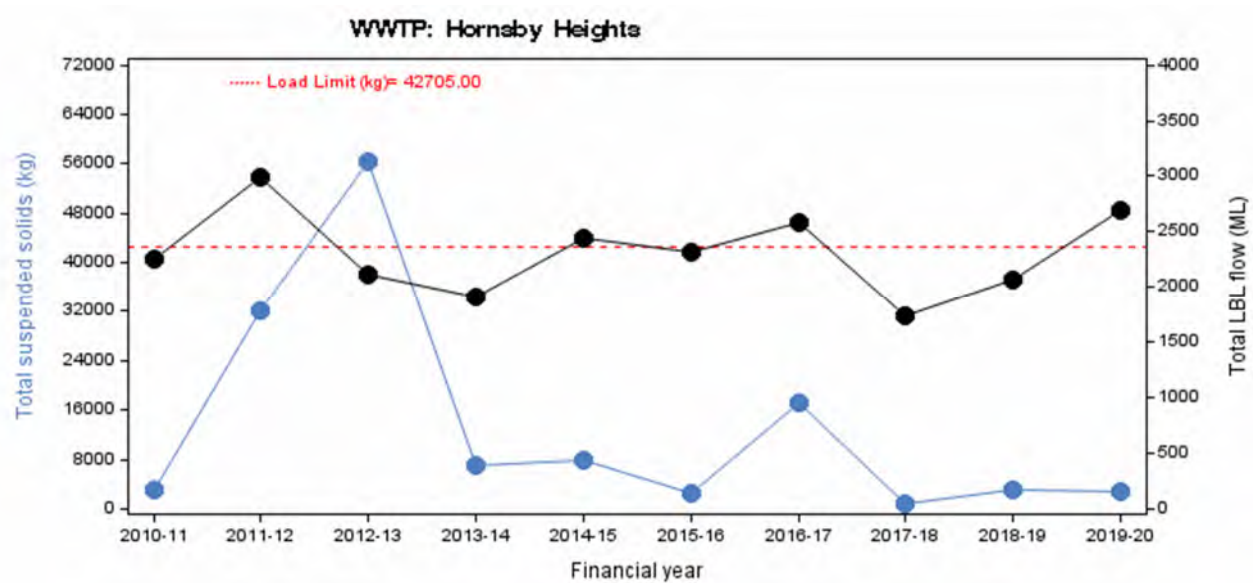
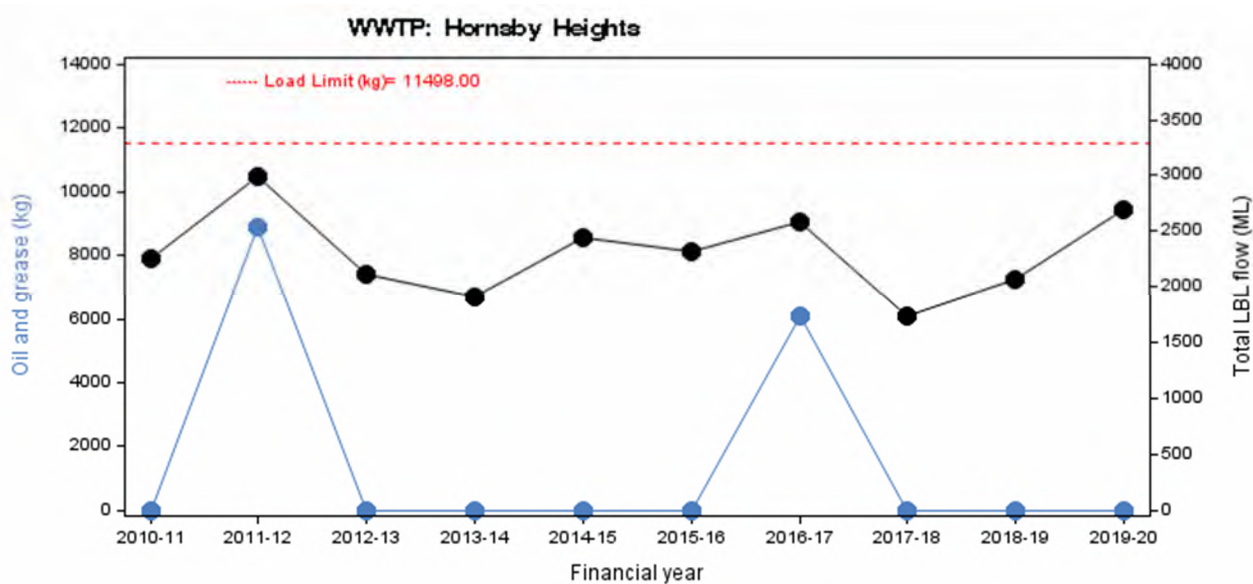
Note: 2019-20 data was compared with previous three years data (2016-2019) due to lab method change in 2016-17. Statistical test was not conducted because >90% of results were below the detection limit.

Discharge load: Nutrients



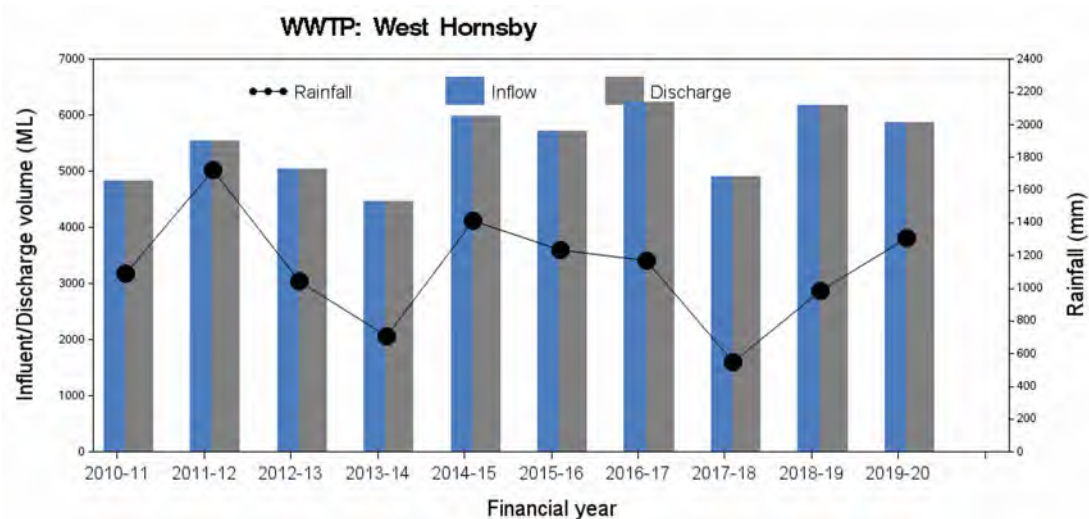
Discharge load: Major conventional analytes



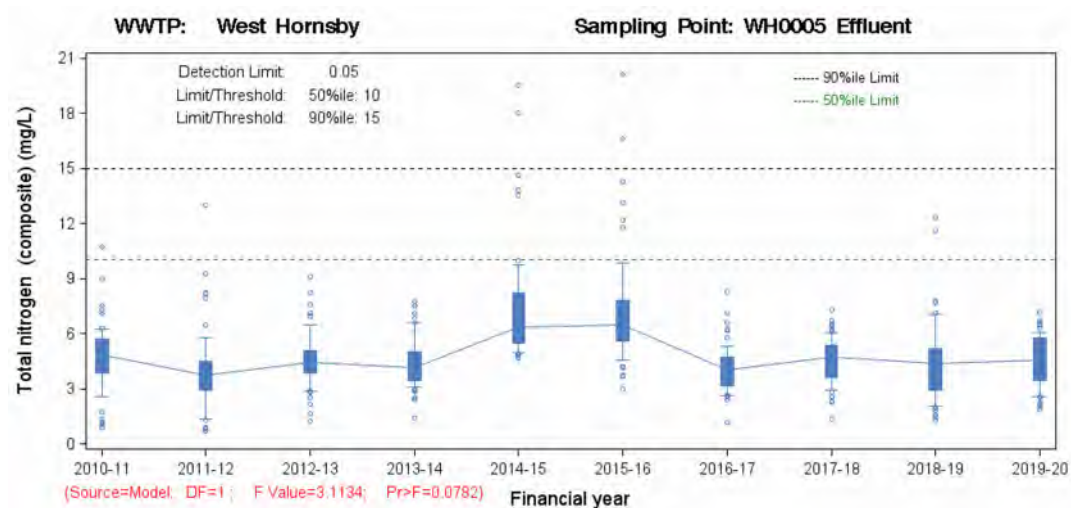
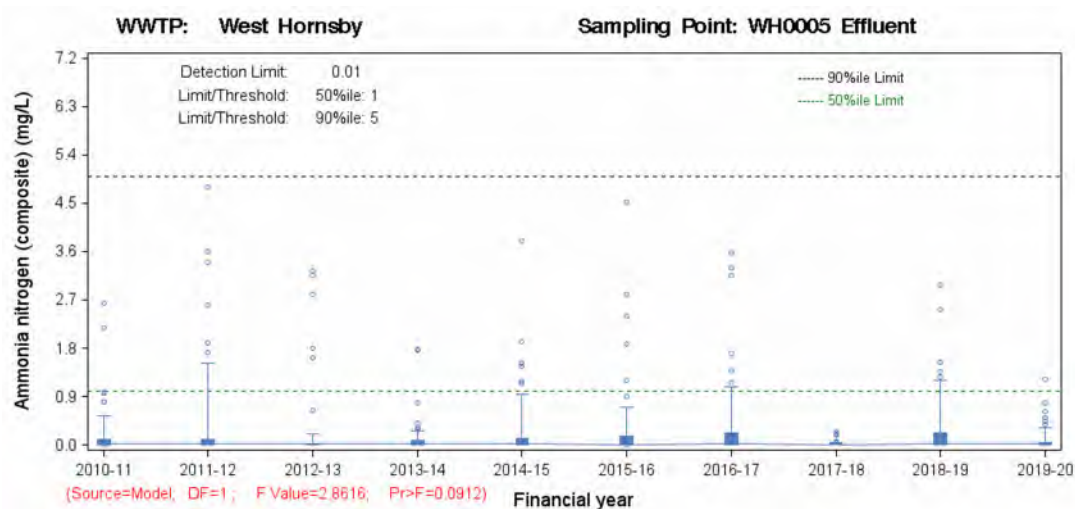


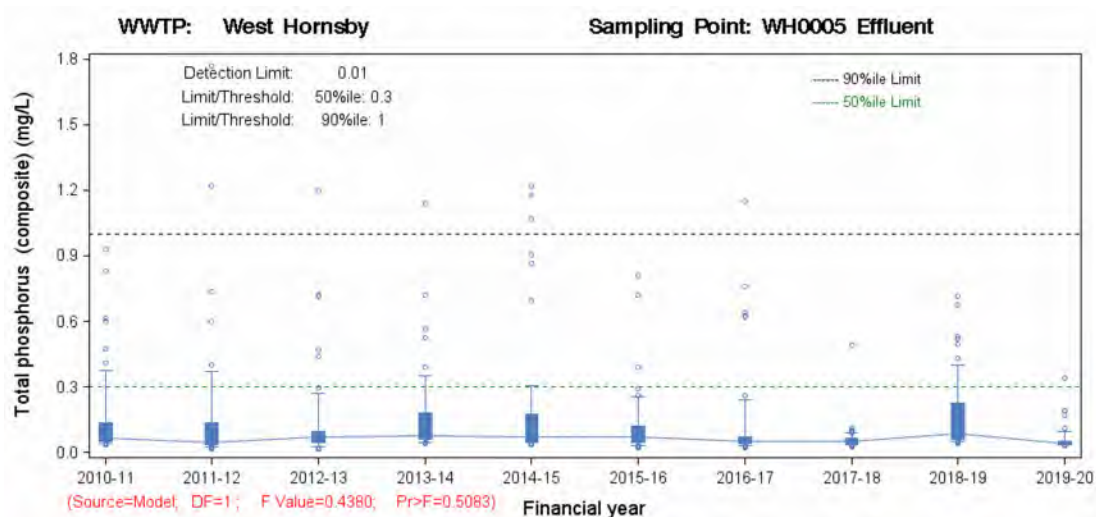
West Hornsby WWTP

Discharge volume and rainfall

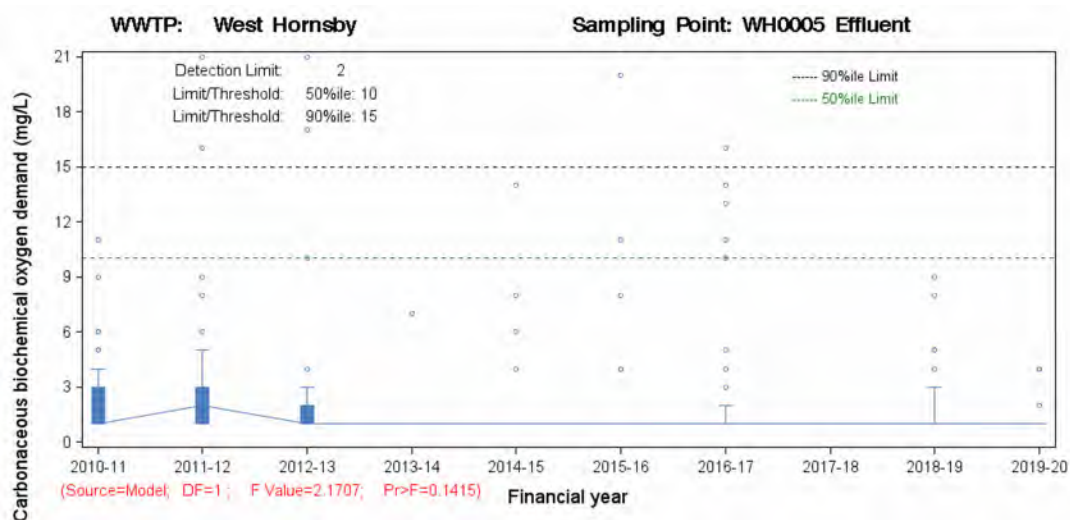


Discharge quality: Nutrients

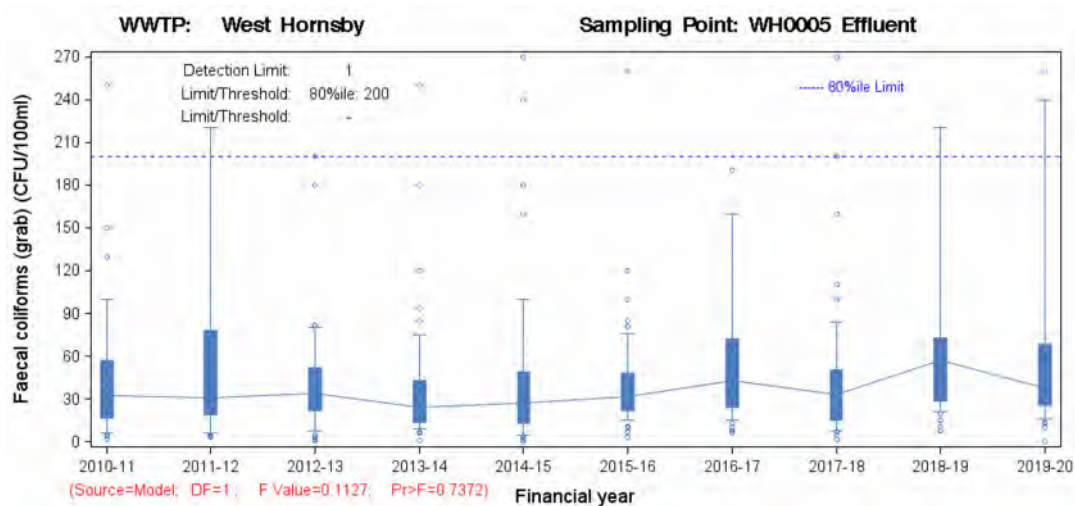


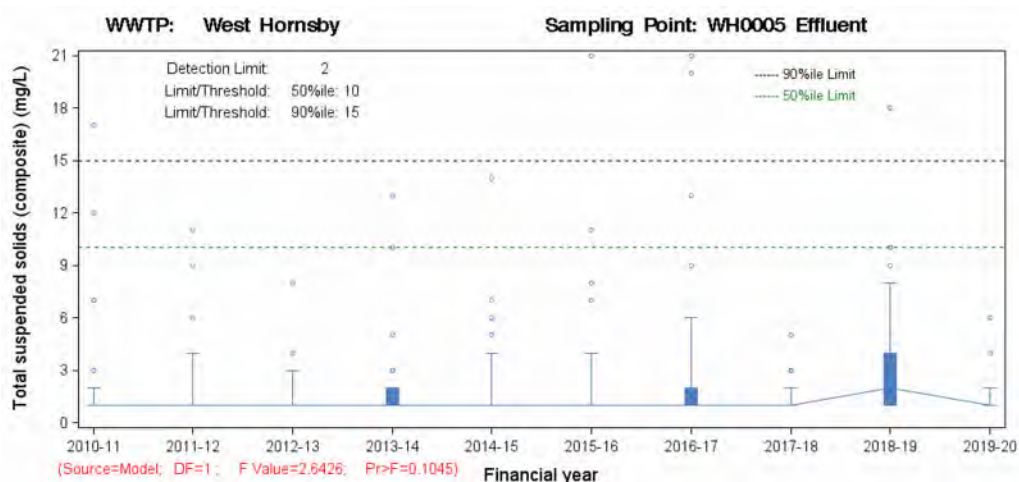


Discharge quality: Major conventional analytes

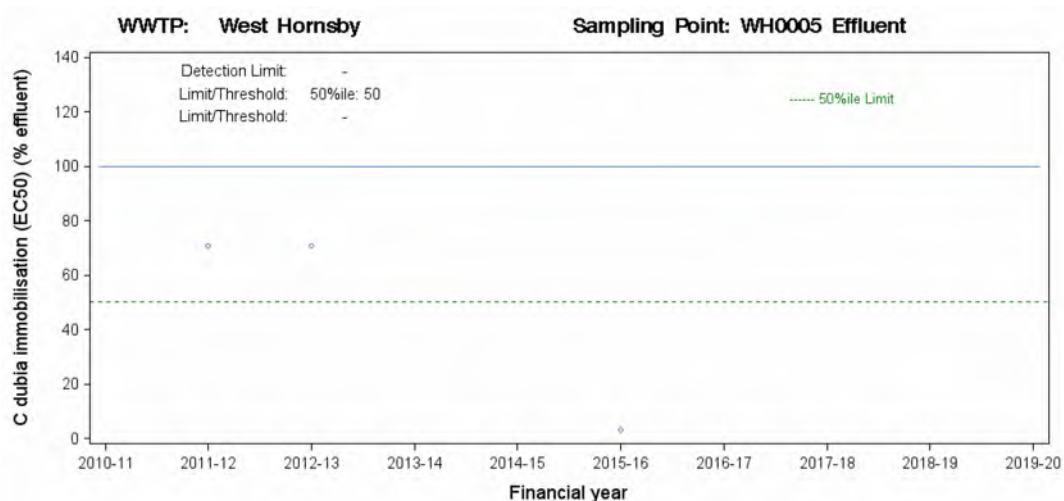


Note: Statistical test was based on 2019-20 data with previous five years data (2014-2019) due to lab method change in 2014-15.



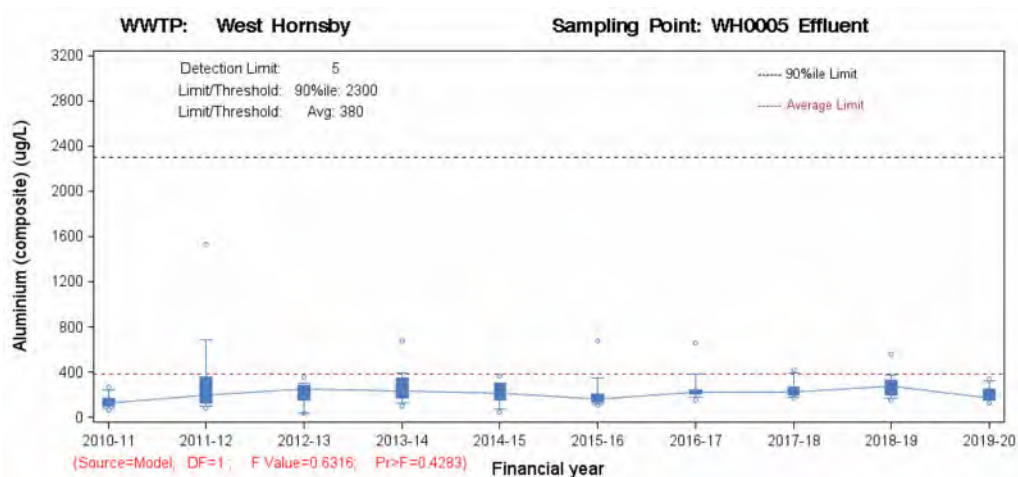


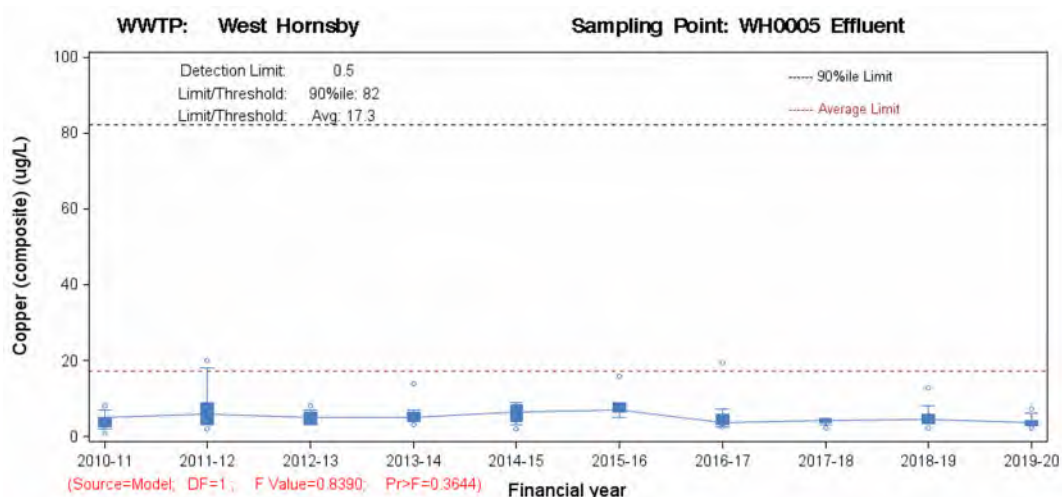
Discharge quality: Toxicity



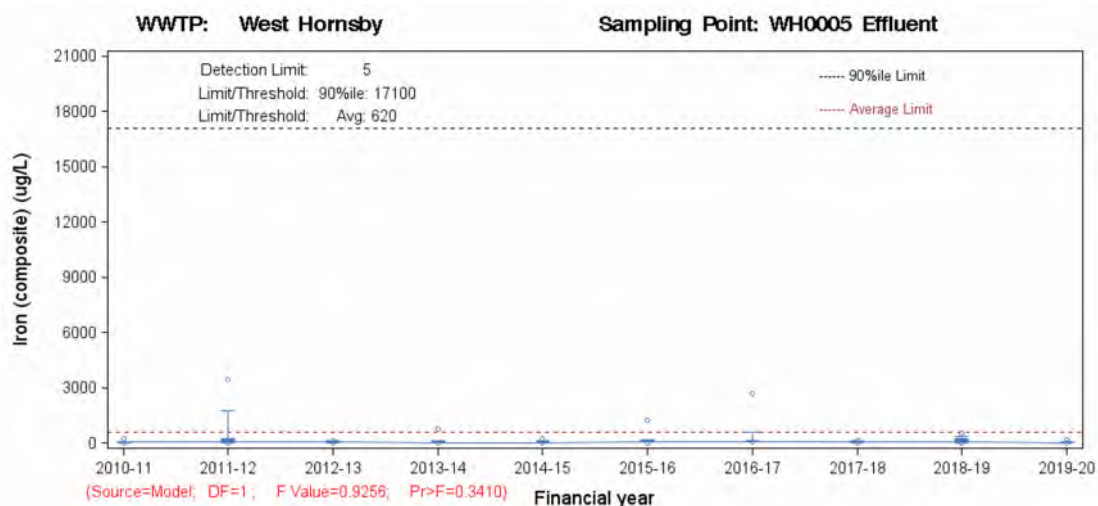
Note: Statistical test was not conducted because >90% of results were recorded at 100% survival for *Ceriodaphnia dubia*.

Discharge quality: Trace metals

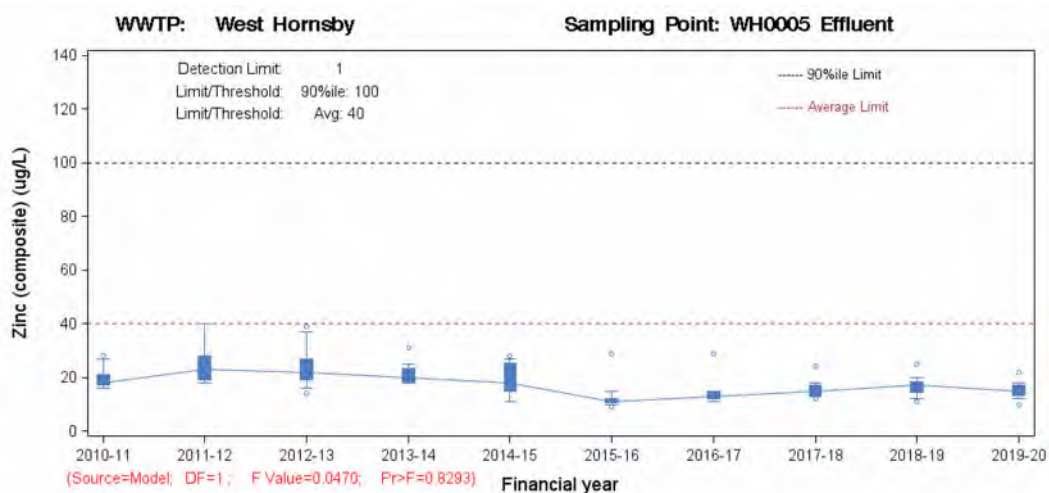




Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

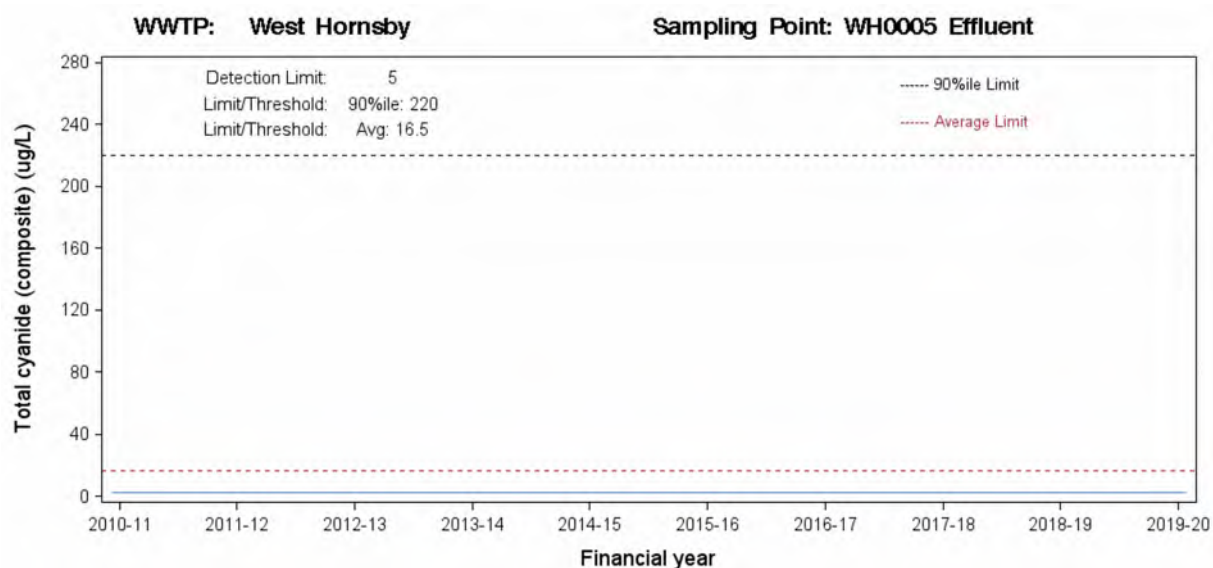


Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

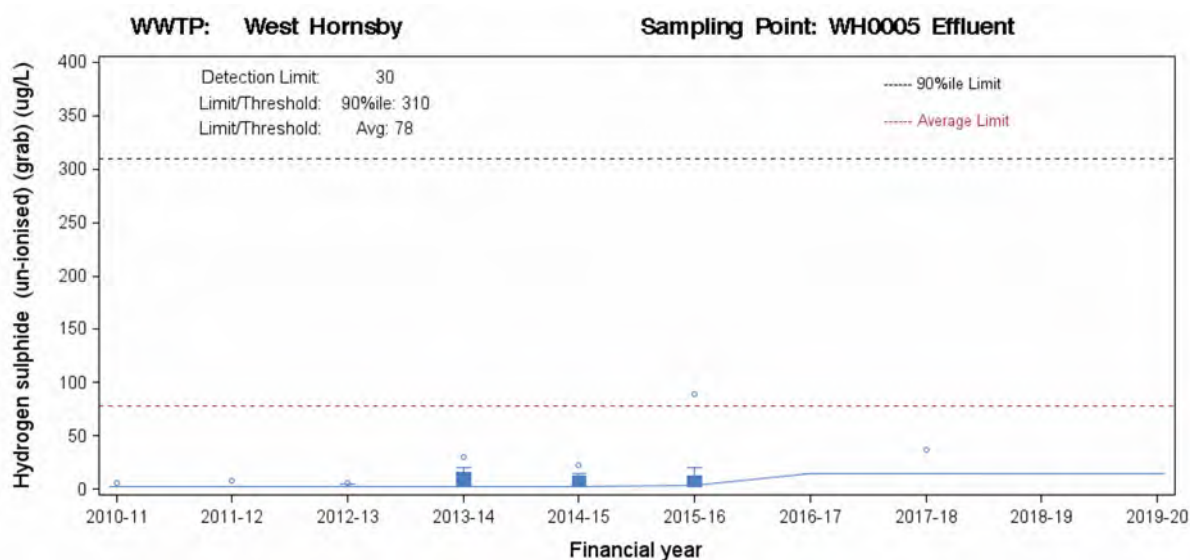


Note: Statistical test was based on 2019-20 data with previous three years data (2016-2019) due to detection limit change in 2016-17.

Discharge quality: Other chemicals and organics (including pesticides)

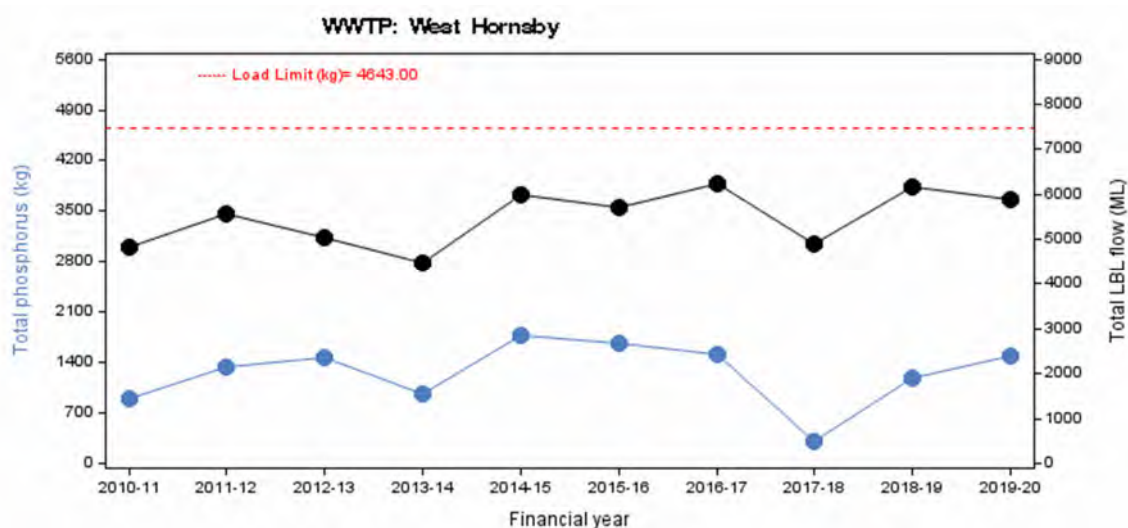
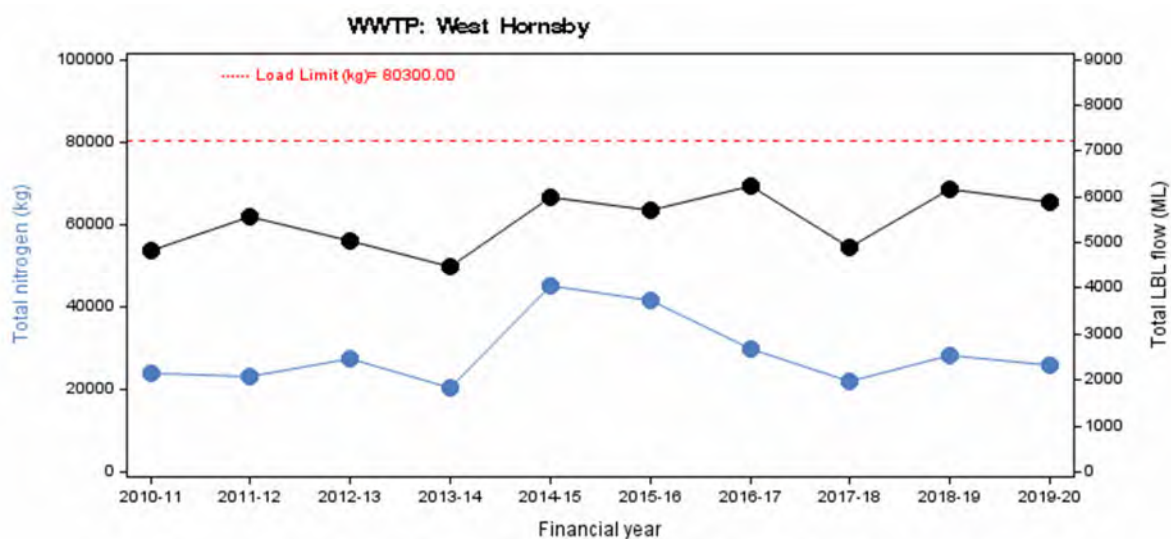


Note: Statistical test was not conducted because >90% of results were below the detection limit.

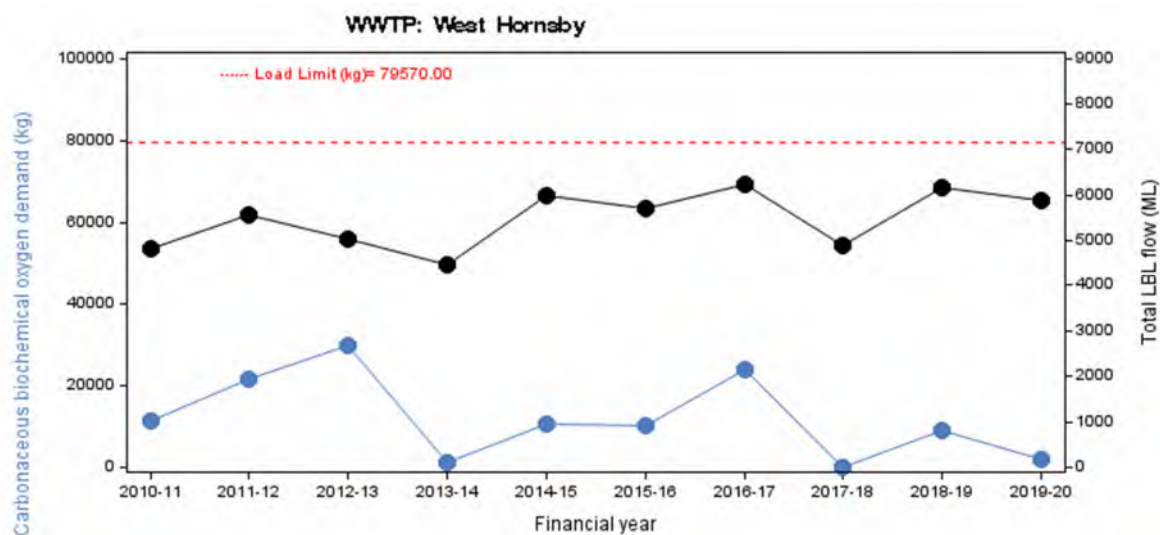


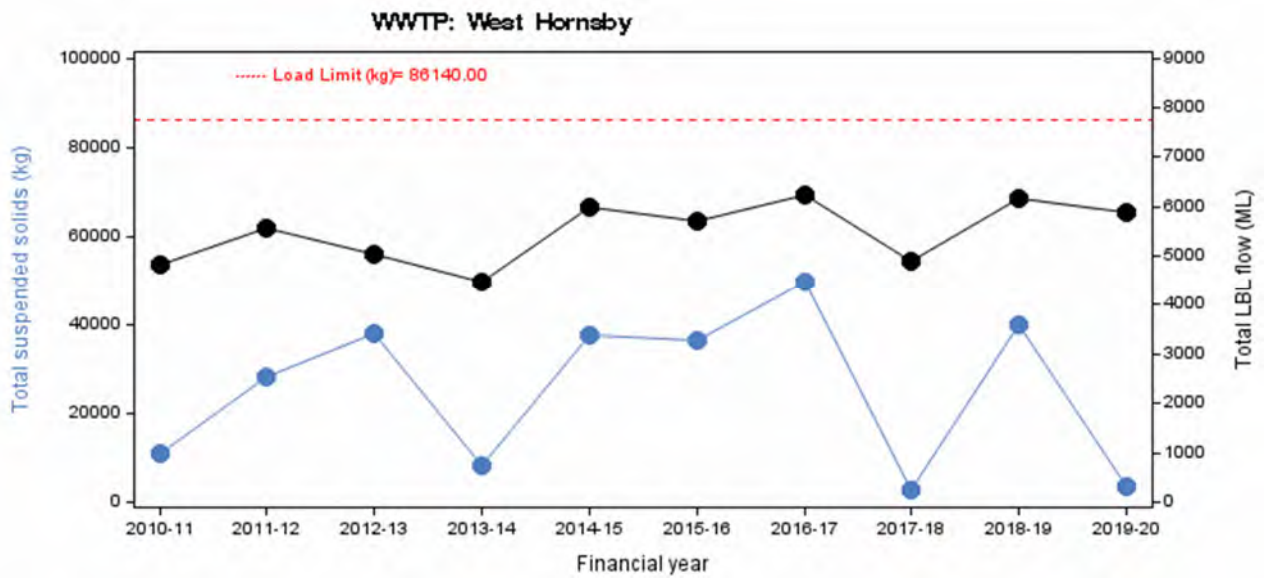
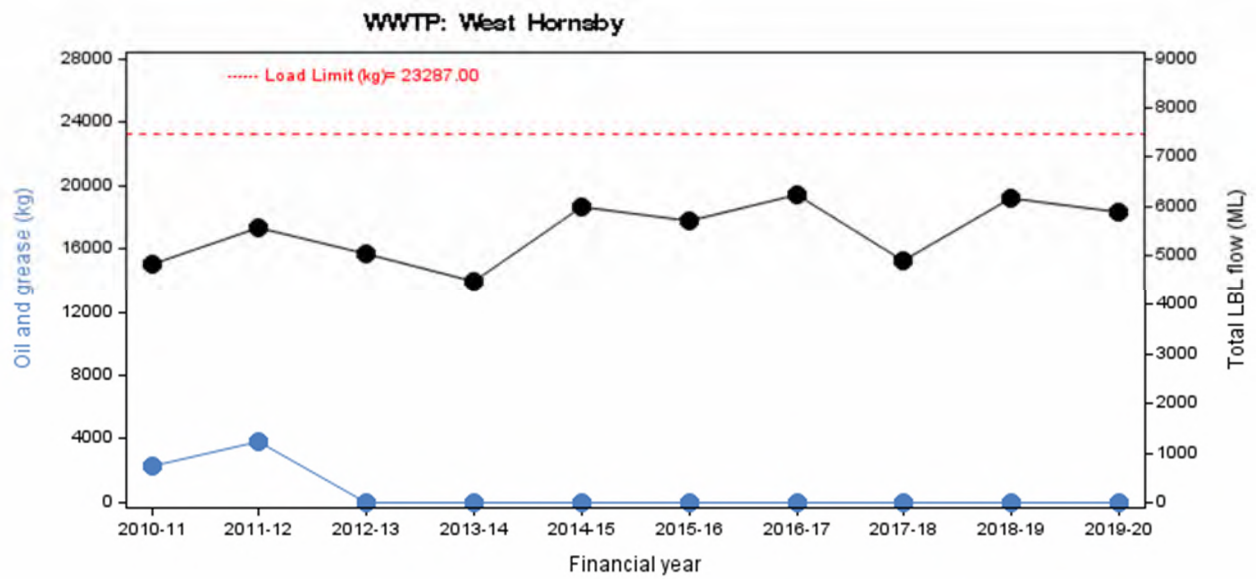
Note: 2019-20 data was compared with previous three years data (2016-2019) due to lab method change in 2016-17.
Statistical test was not conducted because >90% of results were below the detection limit.

Discharge load: Nutrients



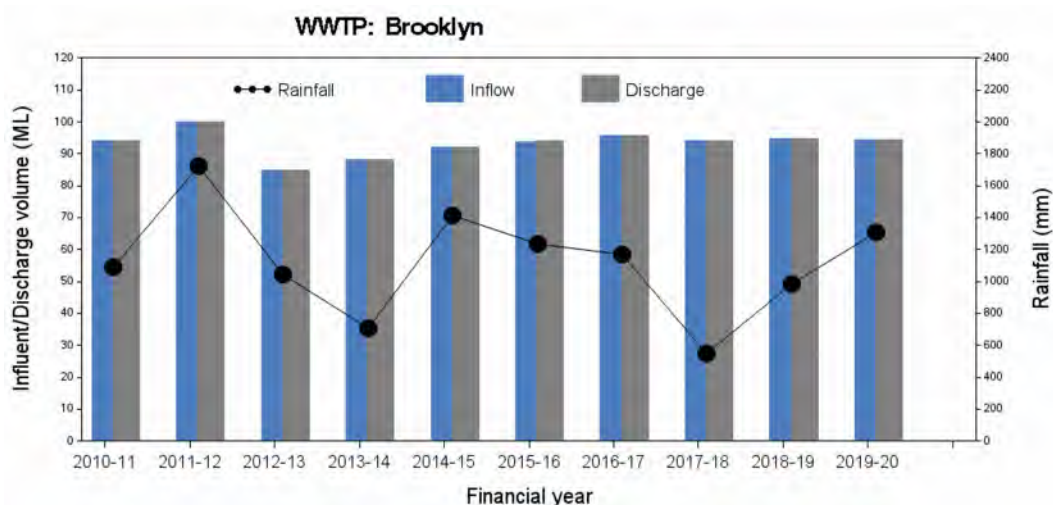
Discharge load Major conventional analytes



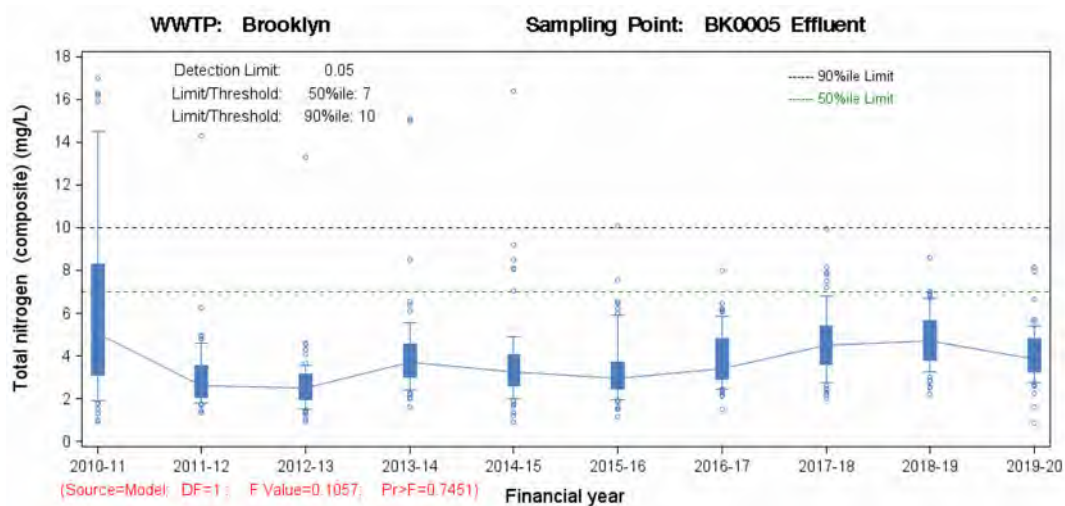
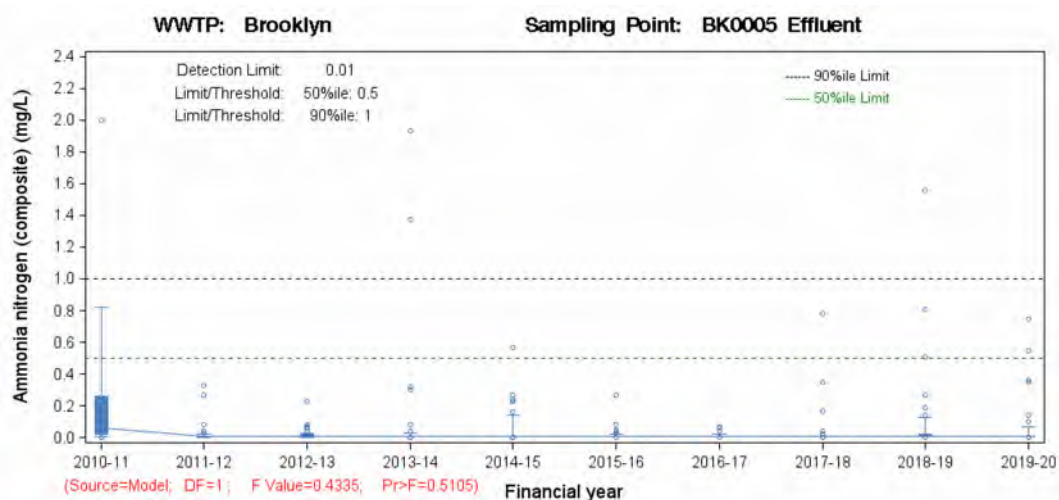


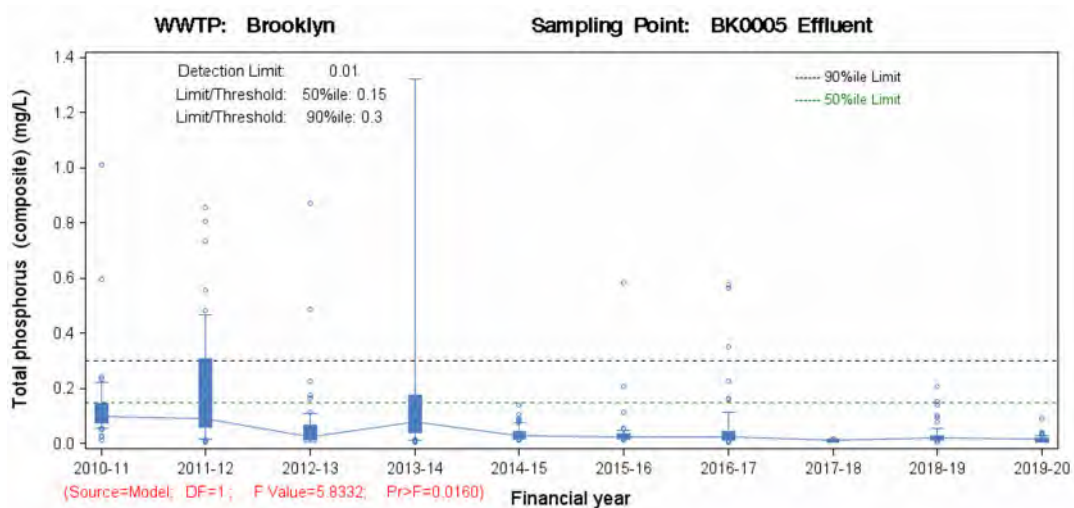
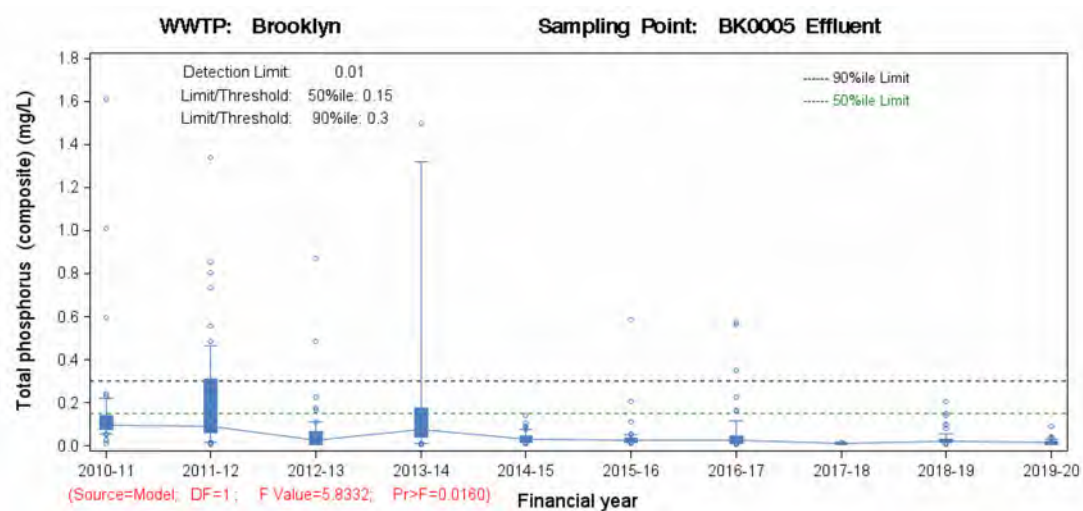
Brooklyn WWTP

Discharge volume and rainfall

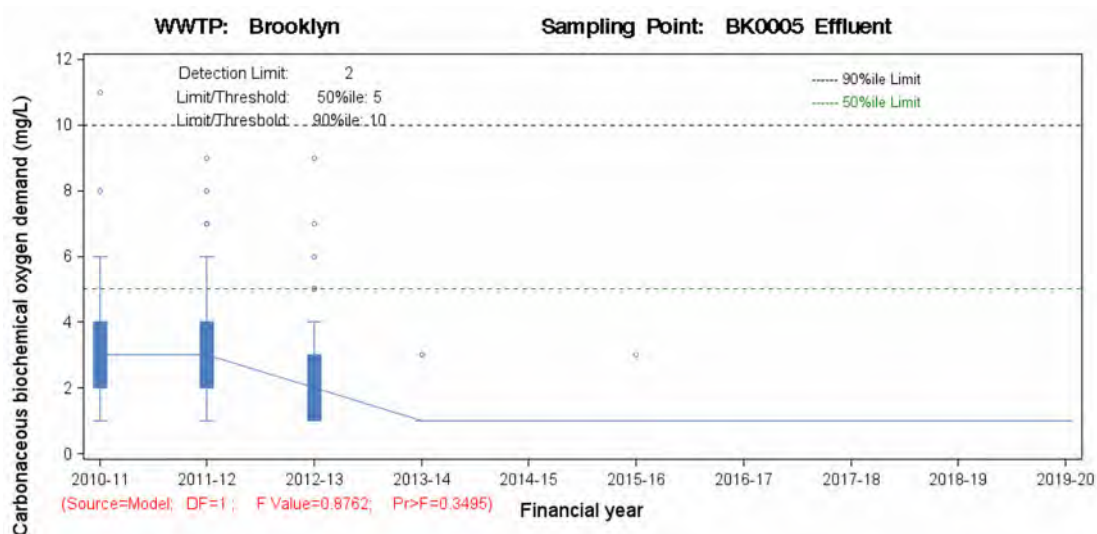


Discharge quality: Nutrients

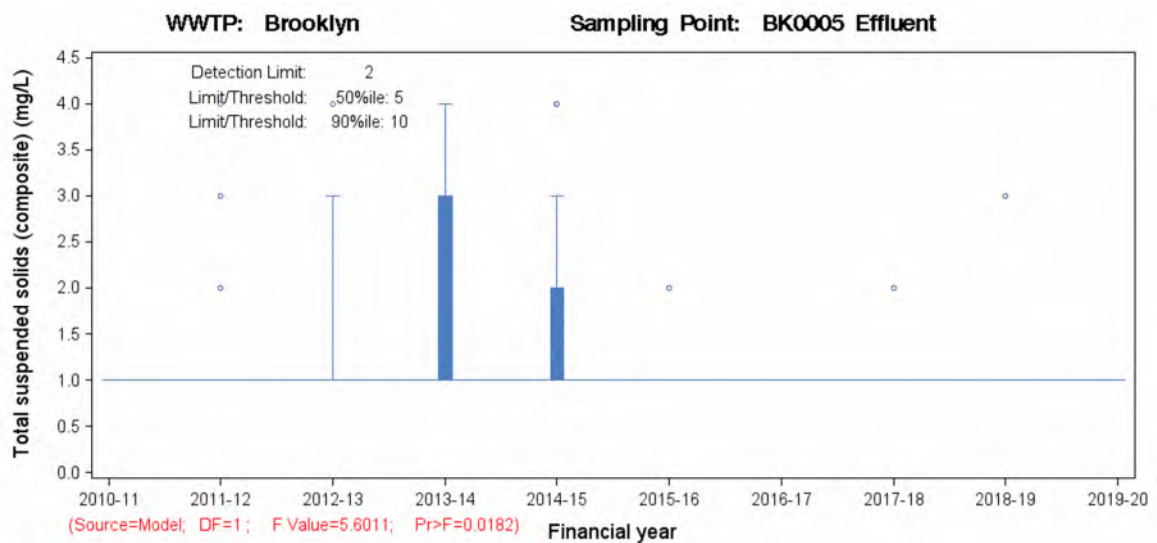
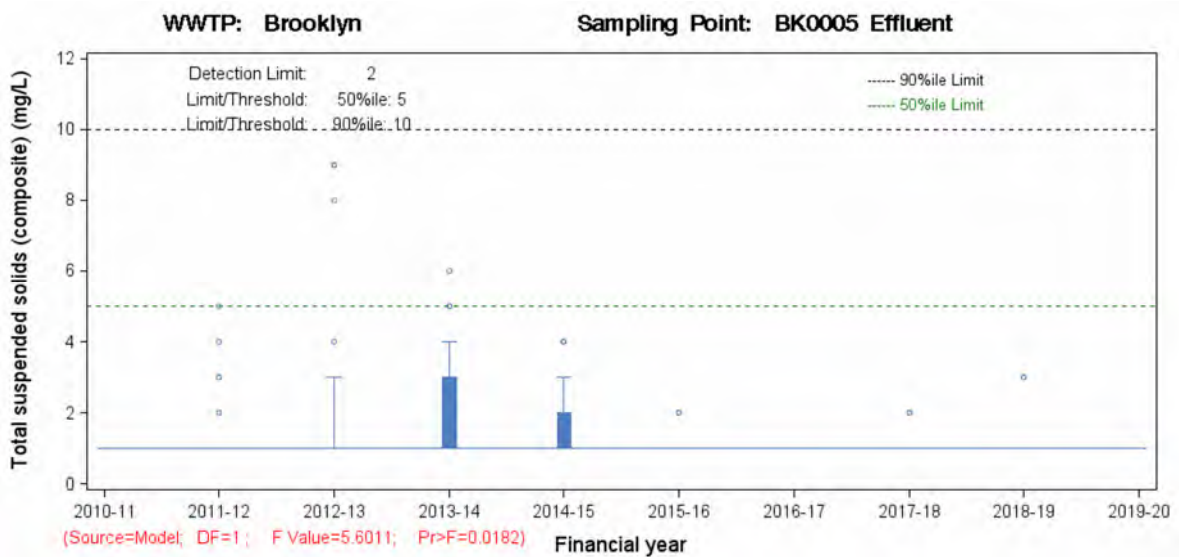
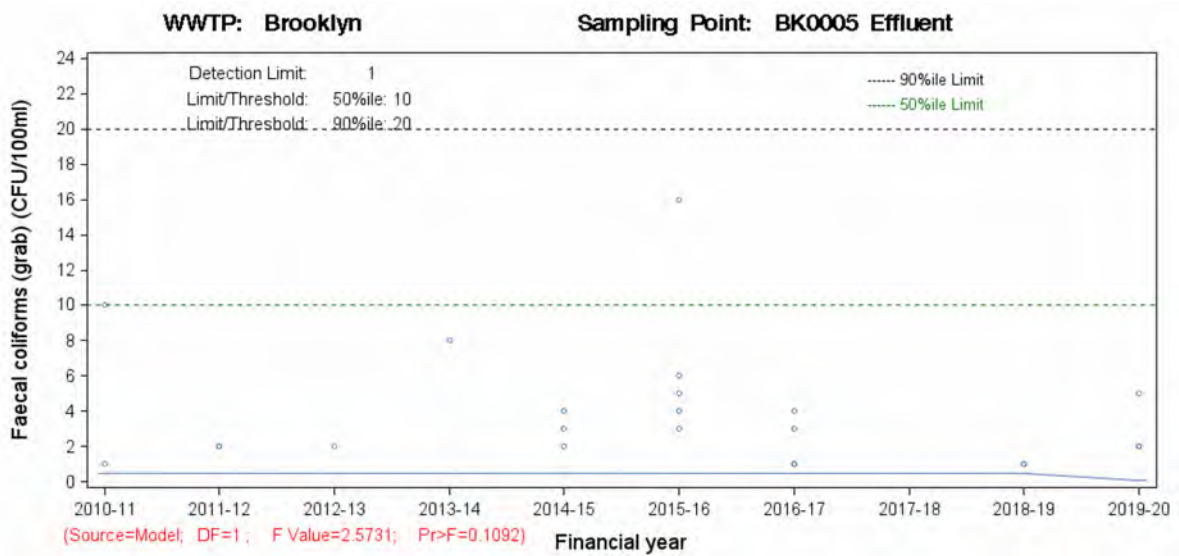


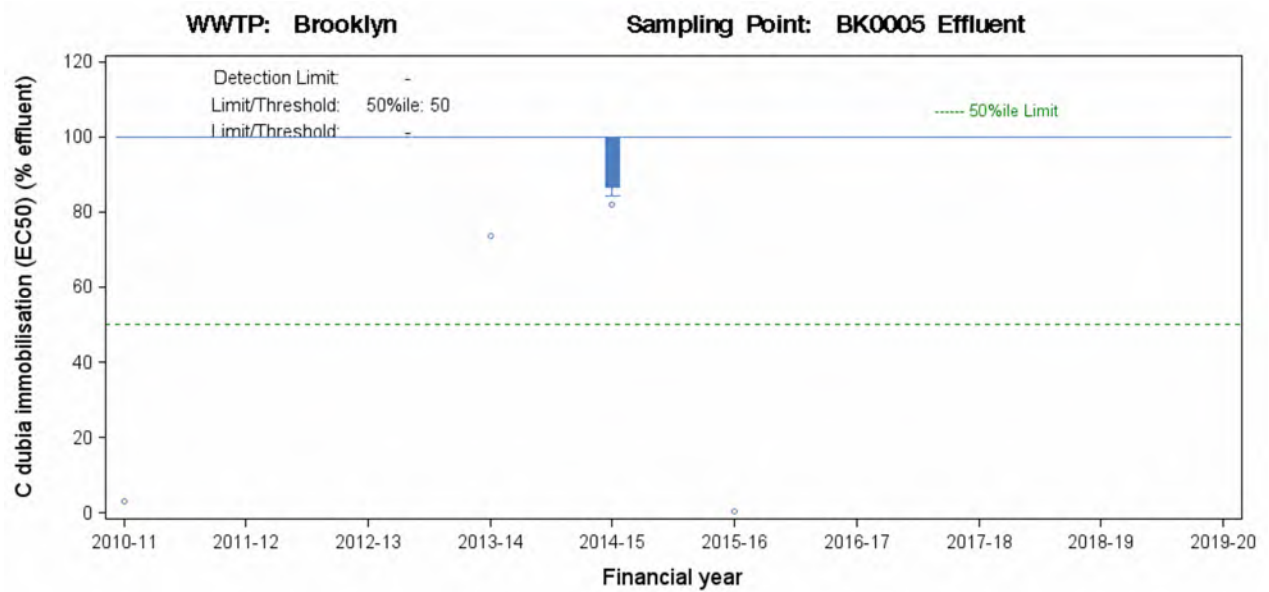


Discharge quality: Major conventional analytes



Note: Statistical test was based on 2019-20 data with previous five years data (2014-2019) due to lab method change in 2014-15.





Note: Statistical test was not conducted because >90% of results were recorded at 100% survival for *Ceriodaphnia dubia*.

Appendix E : Wastewater overflows

Dry weather overflows

Table E-1 Trend in dry weather wastewater overflow frequency and volumes for coastal WWTPs wastewater system (2013-14 to 2019-20)

Wastewater system	2013-14		2014-15		2015-16		2016-17		2017-18		2018-19		2019-20	
	Frequency	Volume (KL)	Frequency	Volume (KL)	Frequency	Volume (KL)	Frequency	Volume (KL)	Frequency	Volume (KL)	Frequency	Volume (KL)	Frequency	Volume (KL)
Warriewood	52	309	34	272	18	62	6	99	6	39	3	27	7	55
North Head / Northern suburbs	441	8,331	406	9,248	241	7,379	98	6,547	147	10,197	170	16,151	176	7,948
Bondi	18	2,154	12	1,208	12	448	24	1,017	16	960	30	1,424	22	1,480
Malabar/Southern suburbs	91	7,837	100	13,997	77	6,803	76	8,098	75	6,112	79	6,853	133	9,530
Cronulla	25	289	26	795	19	424	30	1,030	42	2,205	54	2,279	41	693
Wollongong	17	126	11	188	16	472	9	174	11	132	28	551	27	649
Port Kembla	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Shellharbour	3	8	1	50	4	75	2	75	3	387	3	42	4	172
Kiama/Bombo	2	25	2	13	1	2	1	142	1	7	2	34	2	39
All ocean systems	649	19,080	592	25,771	388	15,664	246	17,182	301	20,039	369	27,361	412	20,567

Table E-2 Trend in dry weather wastewater overflow frequency and volumes for inland wastewater systems (2013-14 to 2019-20)

Wastewater system	2013-14		2014-15		2015-16		2016-17		2017-18		2018-19		2019-20	
	Frequency	Volume (KL)	Frequency	Volume (KL)	Frequency	Volume (KL)	Frequency	Volume (KL)	Frequency	Volume (KL)	Frequency	Volume (KL)	Frequency	Volume (KL)
Picton	4	171	0	0	1	83	5	188	2	22	3	45	4	28
West Camden	5	18	2	16	2	43	4	35	7	1,079	1	7	3	35
Wallacia	0	0	0	0	1	24	2	3	1	13	1	9	0	0
Penrith	13	896	15	483	9	492	6	194	11	287	3	73	10	180
Winmalee	11	250	13	263	13	142	11	441	11	580	8	180	5	99
North Richmond	0	0	0	0	0	0	0	0	0	0	2	14	1	6
Richmond	0	0	0	0	1	0.3	0	0	0	0	0	0	0	0
St Marys	5	1,823	4	151	3	235	2	62	0	0	4	170	8	192
Quakers Hill	38	298	28	153	21	90	2	109	5	123	10	866	4	130
Riverstone	1	11	0	0	1	0.7	0	0	1	87	1	57	2	36
Castle Hill	12	394	9	253	10	342	2	312	4	74	8	213	2	20
Rouse Hill	14	162	10	55	6	32	6	72	1	10	9	318	8	163
Hornsby Heights	19	156	15	81	16	95	6	43	3	2	4	37	9	147
West Hornsby	37	1,186	32	688	13	185	8	123	6	27	9	391	5	100
Brooklyn-Danger Island	0	0	0	0	0	0	0	0	0	0	0	0	0	0
All inland systems	159	5,365	128	2,144	97	1,764	54	1,582	52	2,304	63	2,380	61	1,138

Wet weather overflows

Table E-3 Trend in wet weather wastewater overflow frequency and volumes for ocean WWTPs wastewater system (2013-14 to 2019-20)

Wastewater system	2013-14		2014-15		2015-16		2016-17		2017-18		2018-19		2019-20	
	MOF	SOV (ML)	MOF	SOV (ML)	MOF	SOV (ML)	MOF	SOV (ML)	MOF	SOV (ML)	MOF	SOV (ML)	MOF	SOV (ML)
Warriewood	1	0	2	3	3	159	3	0.5	1	3.5	2	4.8	5	157.7
North Head / Northern suburbs	11	666.7	23	11,181	26	9,076	23	4,000	16	279.9	23	3,801.0	16	9,861.0
Bondi	15	10.6	23	189	23	247	20	94	5	11.7	10	179.5	12	489.1
Malabar/Southern suburbs	14	1303.5	33	15,098	28	10,515	29	5,328	20	2,415.0	28	6,586.5	18	15,593.2
Cronulla	1	0	13	815	9	678	13	94	-	0.03	8	28.0	9	659.7
Wollongong	6	126.5	21	285	6	367	8	86	2	0.2	5	25.0	2	59.3
Bellambi	14	315.7	6	45	14	693	22	234	1	0.0	19	46.2	4	159.8
Port Kembla	6	143.1	7	78	4	503	8	159	2	0.7	4	6.7	2	142.4
Shellharbour	4	121.4	6	223	4	494	4	146	1	1.5	4	2.6	1	106.3
Kiama/Bombo	6	29.1	9	47	4	216	8	72	4	2.5	6	4.1	2	3.0
All ocean systems	78	2,717	143	27,964	121	22,949	138	10,213.5	52	2,715.0	109	10,684.4	71	27,232

MOF: Maximum overflow frequency

SOV: System overflow volume

Table E-4 Trend in wet weather wastewater overflow frequency and volumes for inland WWTPs wastewater system (2013-14 to 2019-20)

Wastewater system	2013-14		2014-15		2015-16		2016-17		2017-18		2018-19		2019-20	
	MOF	SOV (ML)	MOF	SOV (ML)	MOF	SOV (ML)	MOF	SOV (ML)	MOF	SOV (ML)	MOF	SOV (ML)	MOF	SOV (ML)
Picton	0	0	0	0	1	8	0	0	0	0	0	0	1	7.5
West Camden	1	0.4	3	32	3	211	3	3	0	0	2	1.0	1	65.1
Wallacia	0	0	3	14	5	11	5	11	0	0	3	2.2	4	28.6
Penrith	1	0	3	27	5	22	4	0.3	0	0	4	12.2	6	173.0
Winmalee	0	0	2	0.1	0	0	0	0	0	0	1	0.1	2	98.0
North Richmond	0	0	2	13	2	17	8	11	0	0	2	0.4	3	15.6
Richmond	0	0	2	1.2	0	0	0	0	0	0	0	0	1	2.1
St Marys	3	8.2	10	222	5	400	5	38	0	0	10	71.7	6	399.7
Quakers Hill	4	20.4	10	744	7	693	10	162	1	12.2	8	280.0	4	538.2
Riverstone	1	0.0	1	12	2	30	3	3.5	0	0	2	0.5	1	34.9
Castle Hill	1	0.4	2	49	2	32	2	1	0	0	4	4.6	2	75.5
Rouse Hill	0	0	1	140	3	94	3	0.3	0	0	2	8.1	1	111.9
Hornsby Heights	1	0.03	1	0.4	1	1	0	0	0	0	0	0	1	1.1
West Hornsby	1	0.03	5	125	5	162	2	11	0	0	8	42.9	2	91.8
Brooklyn-Danger Island	0	0.0	0	0	0	0	0	0	0	0	0	0	0	0.0
All inland systems	13	29.5	45	1,380	41	1,680	45	241	1	12.2	46	423.7	15	1,643



Appendix F : Ocean receiving water

The 2019-2020 summary of modelled chemical concentrations near deepwater ocean outfalls is presented in the separate report titled the 2020 Ocean Sediment Program Assessment Report. Context for that separate report is outlined in Appendix G.





Appendix G : Ocean sediment program

See the separate report titled the 2020 Ocean Sediment Program Assessment Report. Monitoring under the Ocean Sediment Program enables assessment of the longer-term performance of the deepwater ocean outfalls and provide a mechanism to alert for development of possible long-term accumulative effects. The 2020 report analyses previously collected assessment data from the years of 2002, 2005, 2008, 2011, 2014, and 2016 along with relatively recently collected 2020 data.



Appendix H : Harbour and beaches

The analysis of the Beachwatch data has been designed to identify potential wastewater overflows or leakage under dry weather conditions. Overflows or leakage reaching the waterways during dry weather conditions pose a risk to public health. The wet weather public health risk for recreational activities in waterways (harbour and beaches) are well known.

Assumptions behind the data for Beachwatch analysis:

- *Enterococci* results without a respective conductivity value were excluded. Conductivity results for many sites were not available prior to 2013. Conductivity data is required to separate dry weather data from wet weather data.
- Only dry weather results were included in these plots. *Enterococci* results associated with conductivity below 30,000 $\mu\text{S}/\text{cm}$ were considered wet weather and not included in these plots
- Data labels are shown in plots for all *Enterococci* values ≥ 230 cfu/100mL, which is the secondary contact recreation guideline (ANZECC 2000).

The Beachwatch results are presented in the following order similar to monitoring programs and sub-catchments as stated in the method section of Volume 1:

Sydney Beaches

- Northern Sydney
- Central Sydney
- Southern Sydney

Illawarra Beaches

- Wollongong
- Shellharbour
- Bombo

Harbours

- Botany Bay and Georges River
- Port Hackings
- Port Jackson
- Middle Harbour
- Pittwater

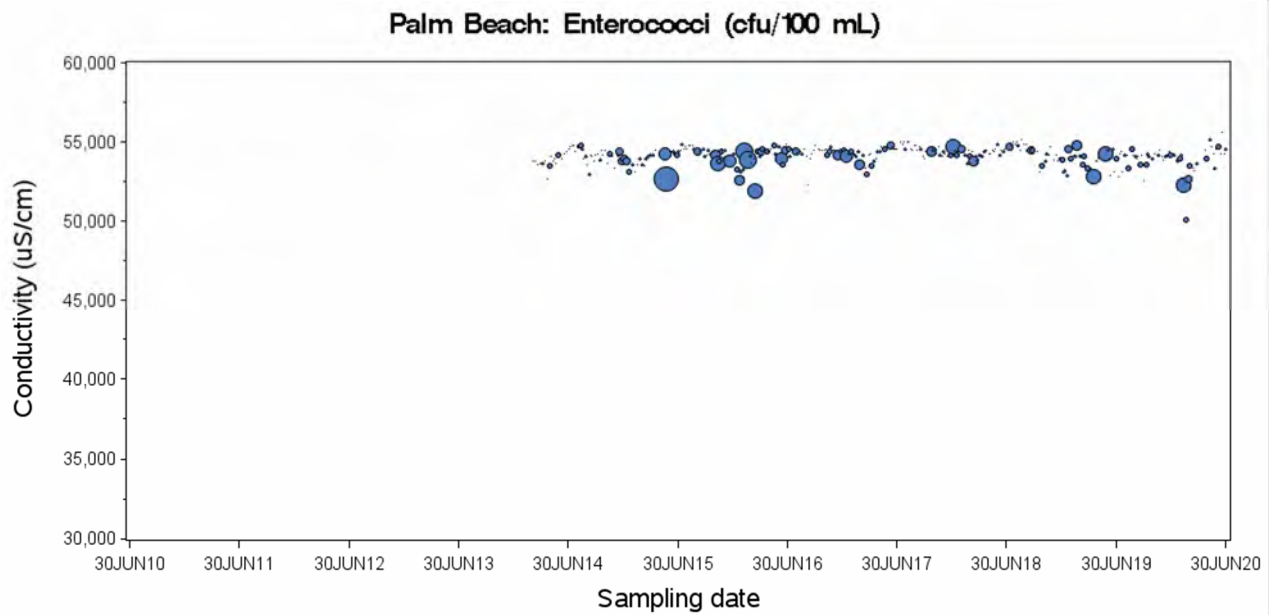
The sites under each sub-catchment are presented in the order from north coast to south coast. When the sub-catchment is a harbour with sites on both coasts then sites on south coasts were stated first and then following clockwise direction to the north coast.

Note: The size of the bubble can't be compared between plots precisely due to software limitations. The bubble size for each site varied based on maximum value for that site using the following ranges, which helped in adjusting the size of bubble for comparison between plots.

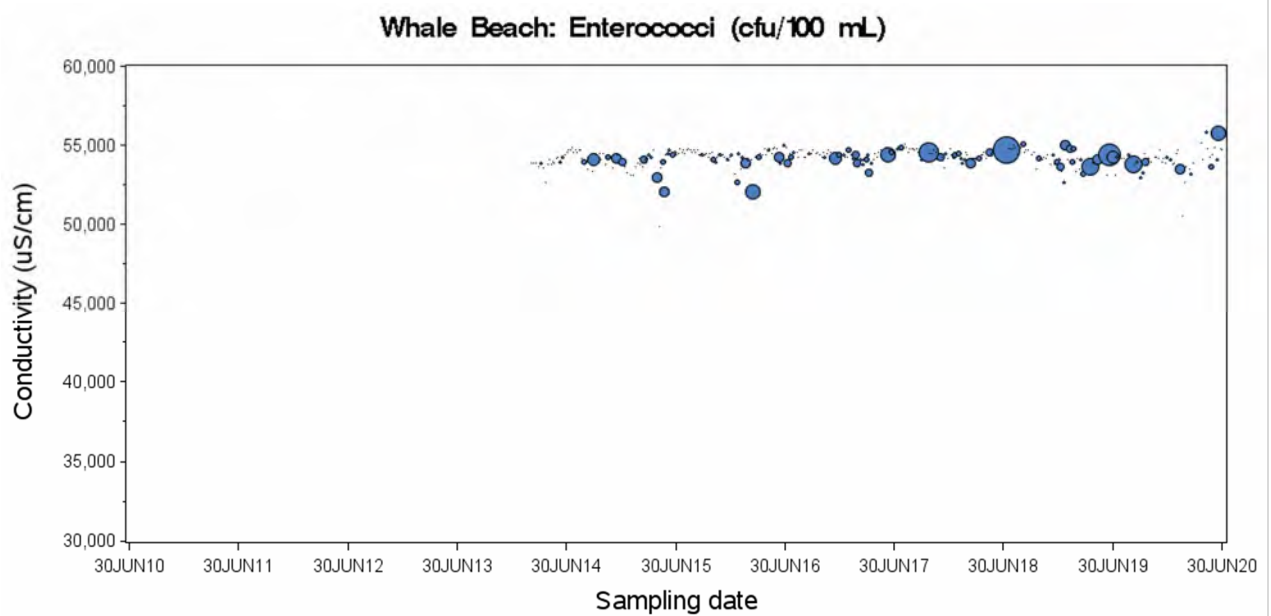



Bubble size	Range of maximum <i>Enterococci</i> value (cfu/100mL)
5	<200
6	200 to 399
7	400 to 599
8	600 to 799
9	800 to 999
10	1,000 to 2,999
11	3,000 to 5,999
12	6,000 to 9999
15	10,000 or more

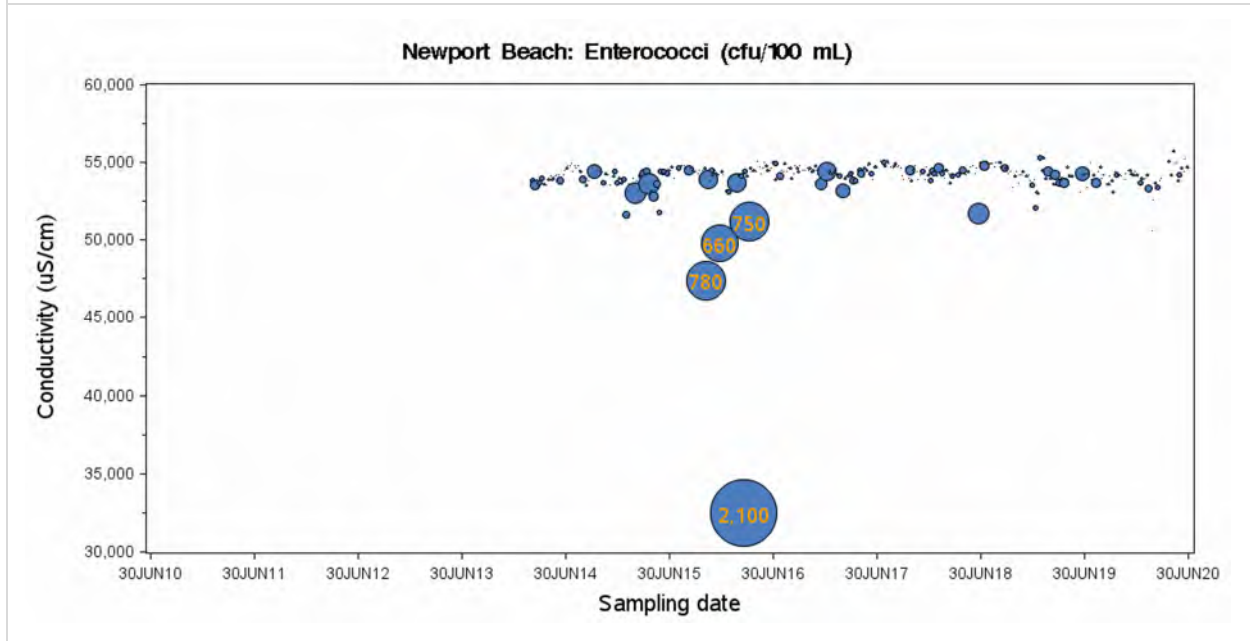
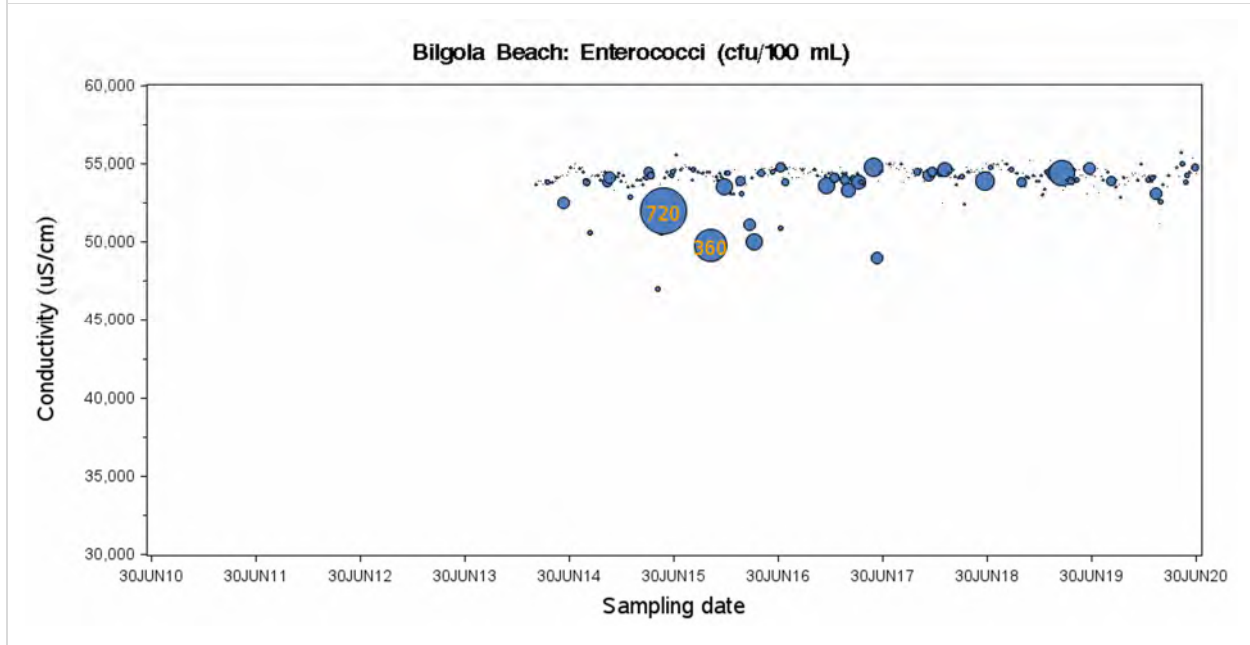
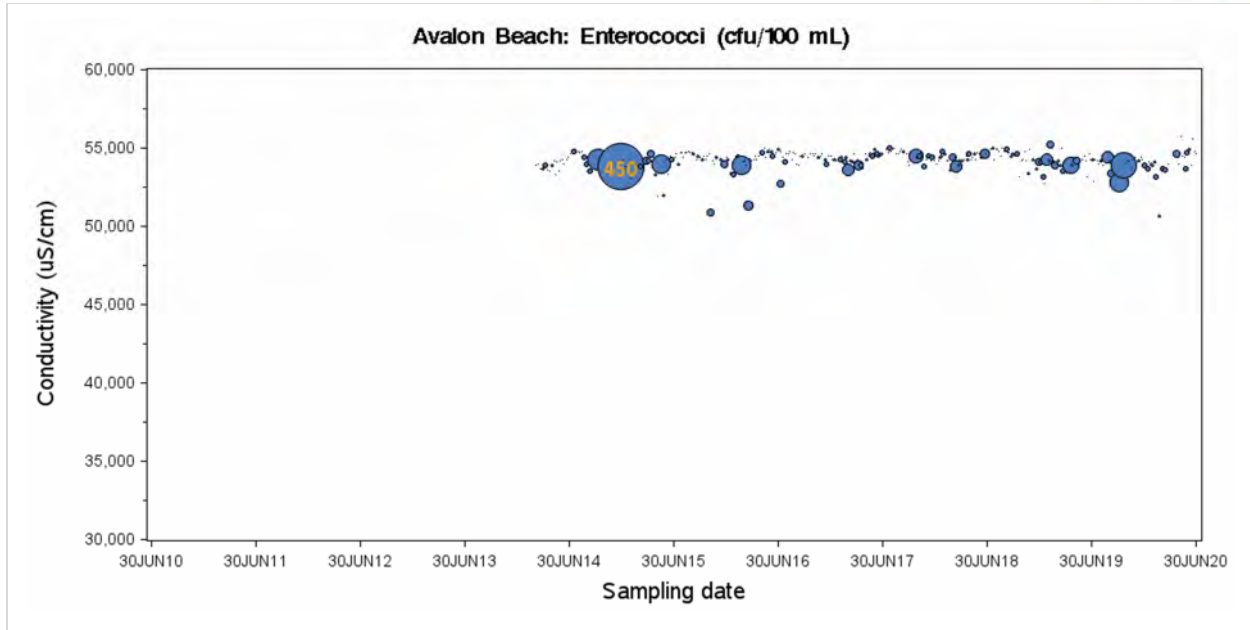
Sydney Beaches: Northern Sydney

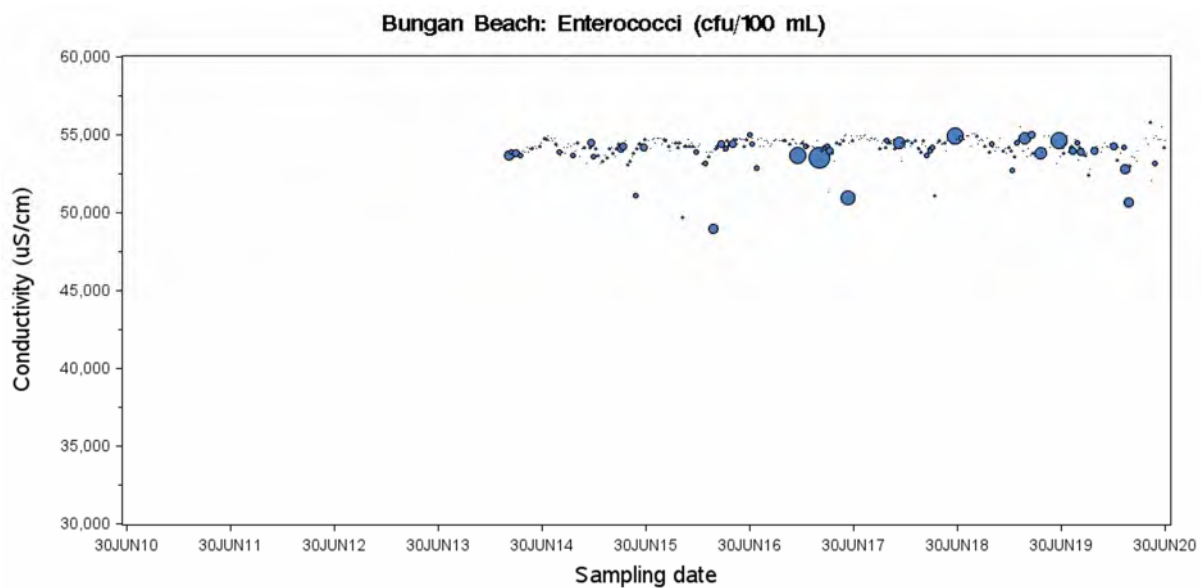


Note: No extreme values found (≥ 230 cfu/100mL) to mark using data labels

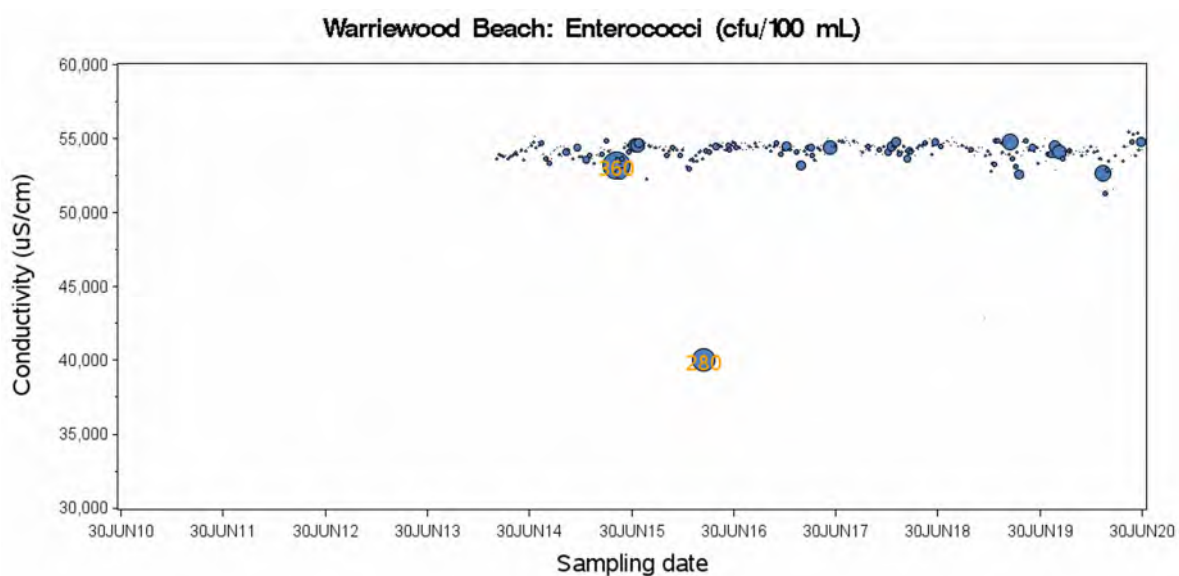
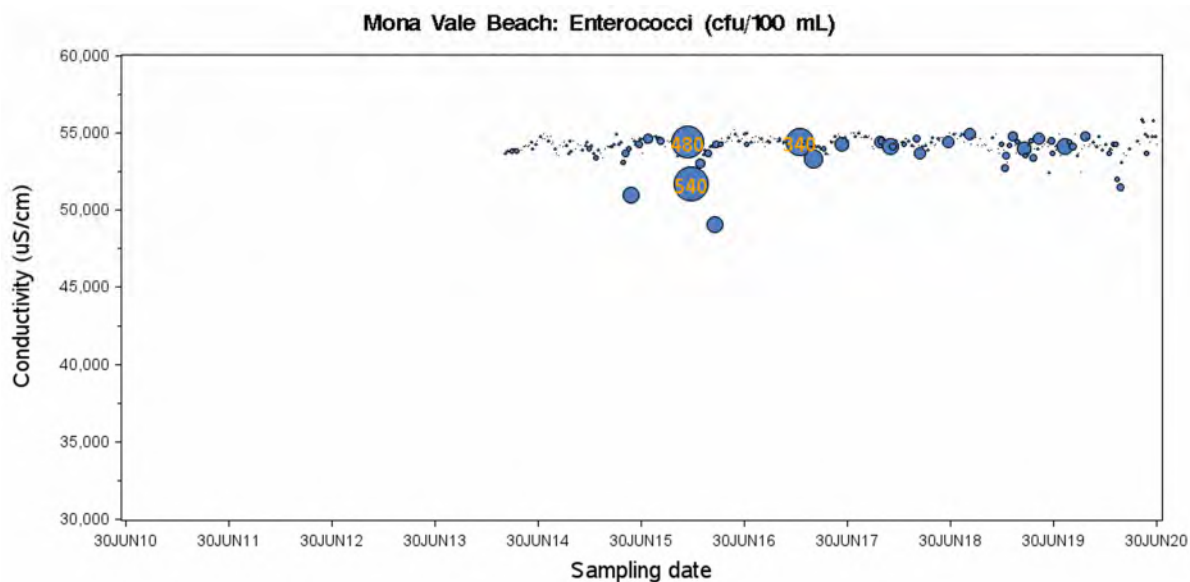


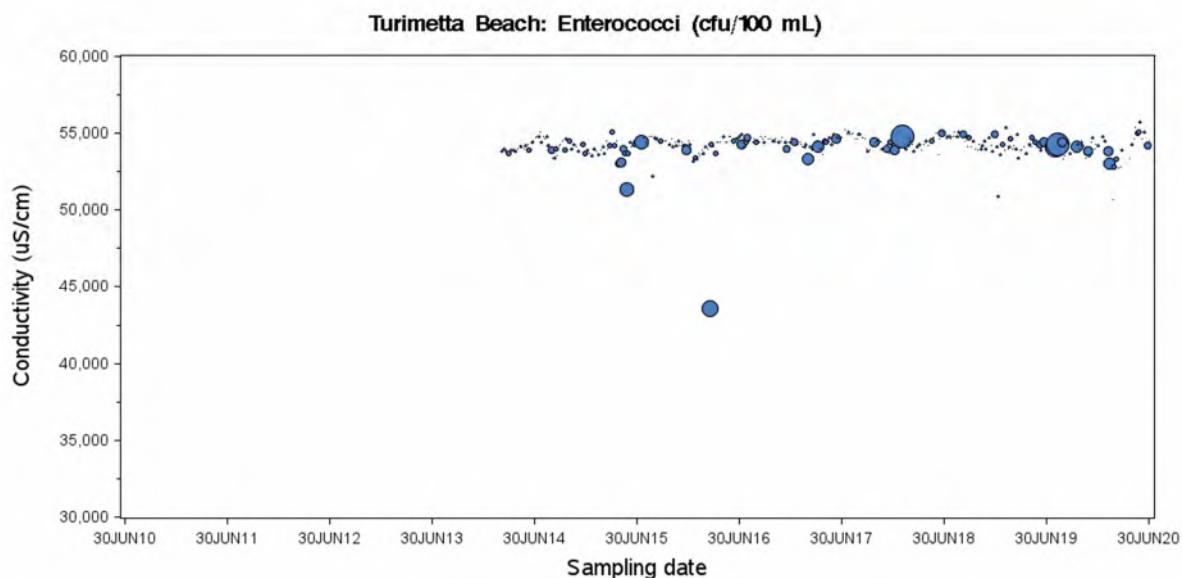
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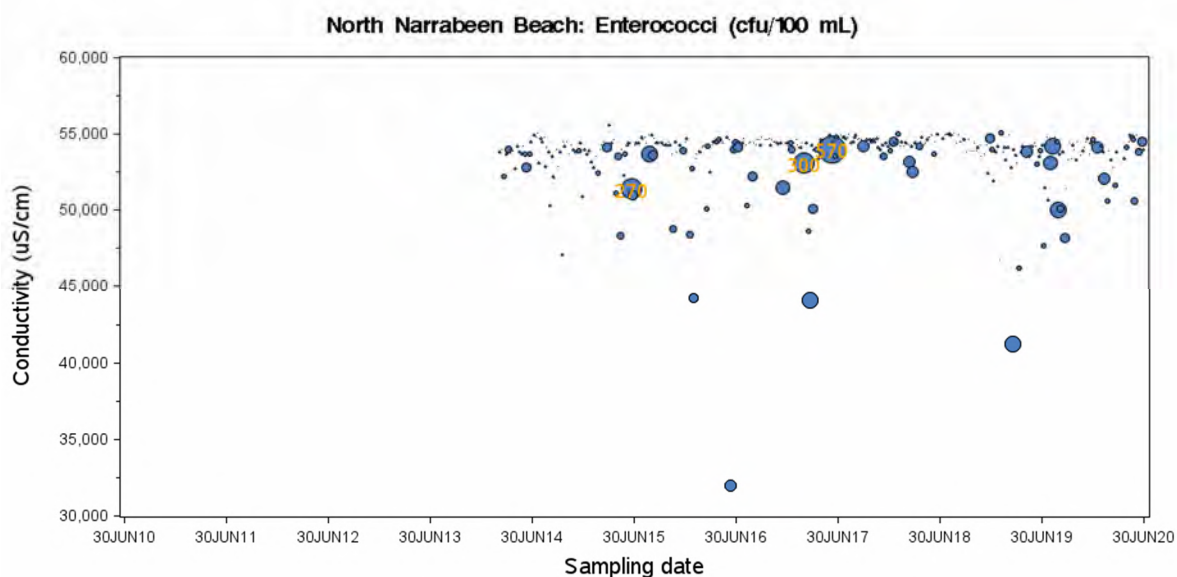
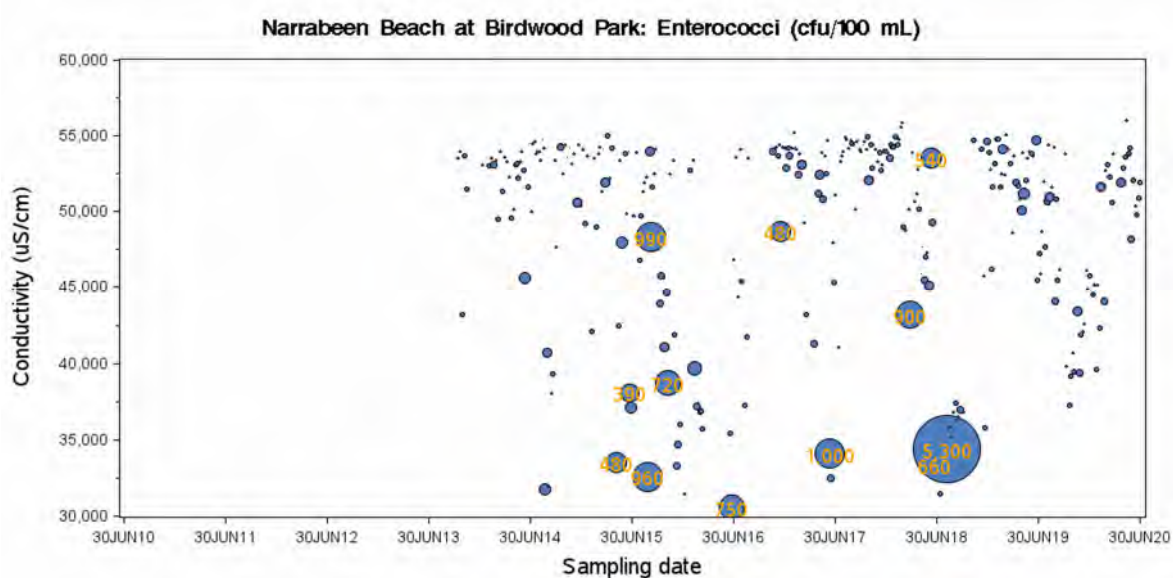


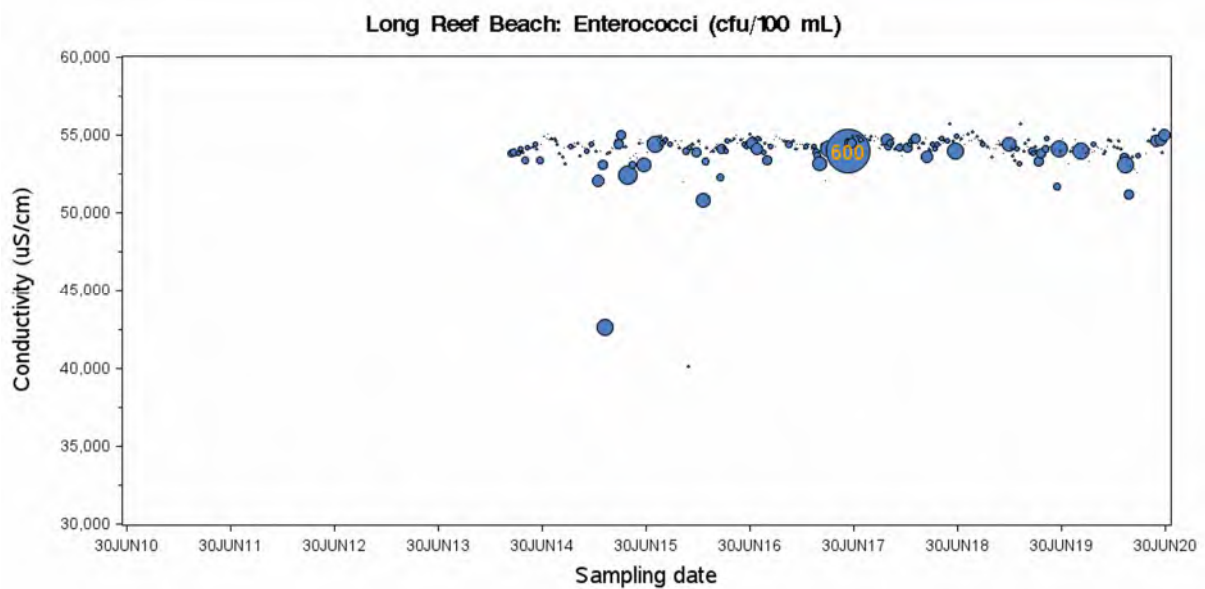
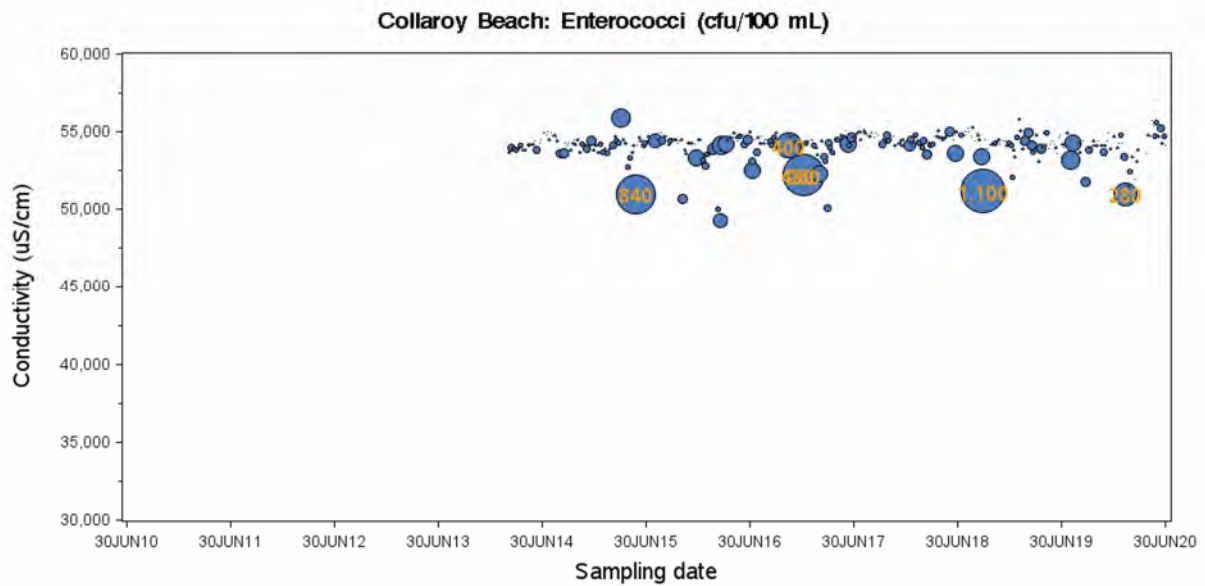
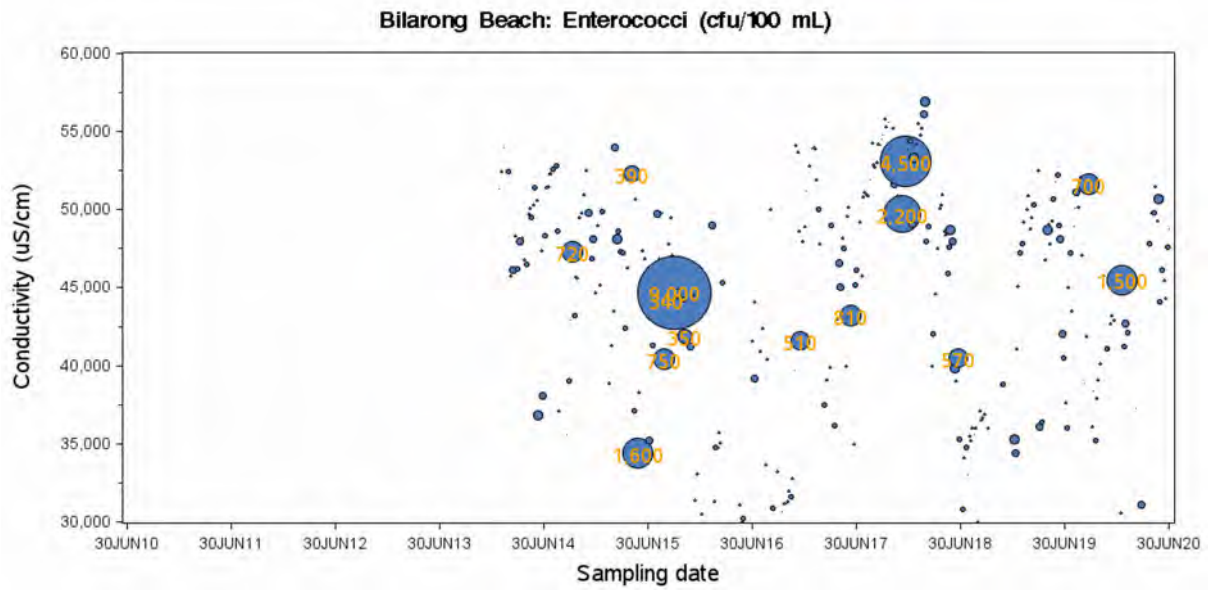
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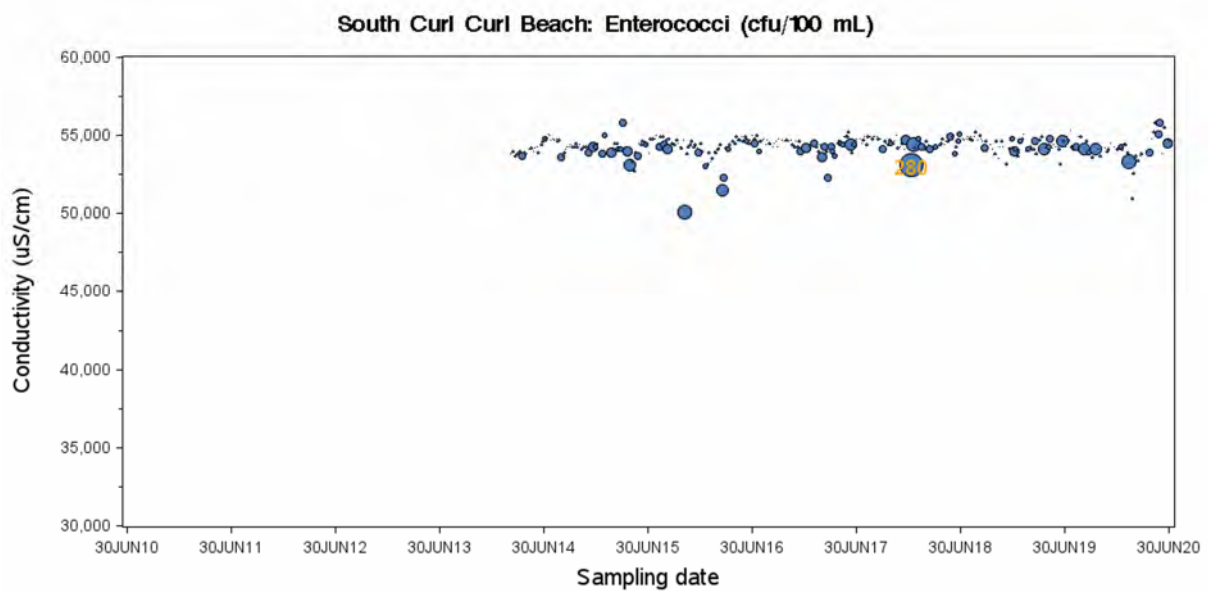
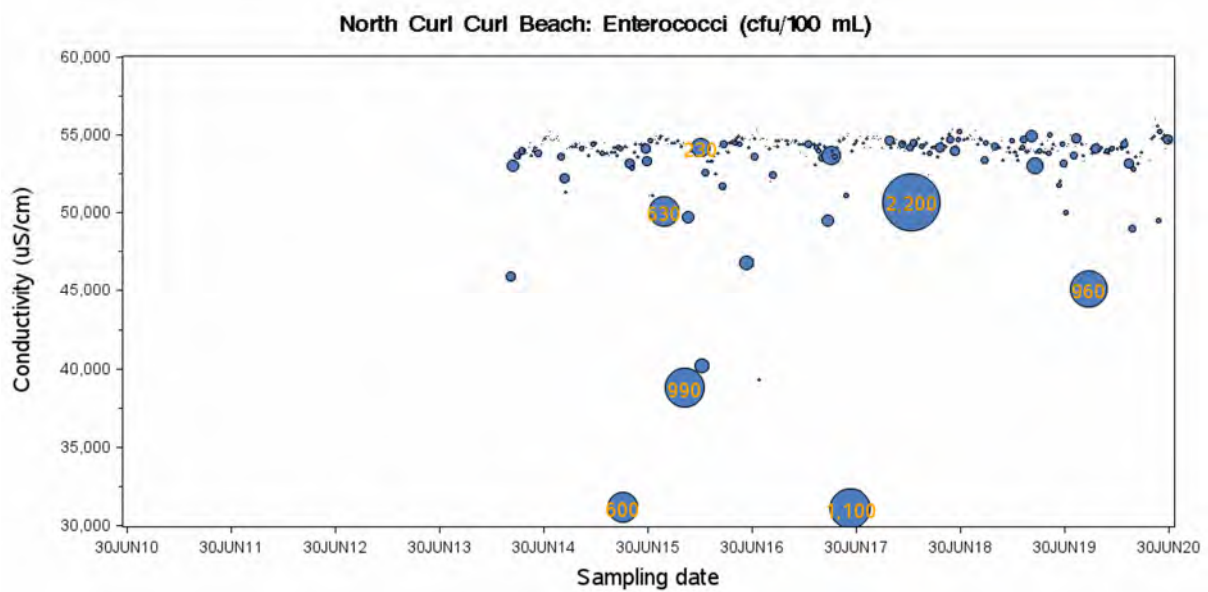
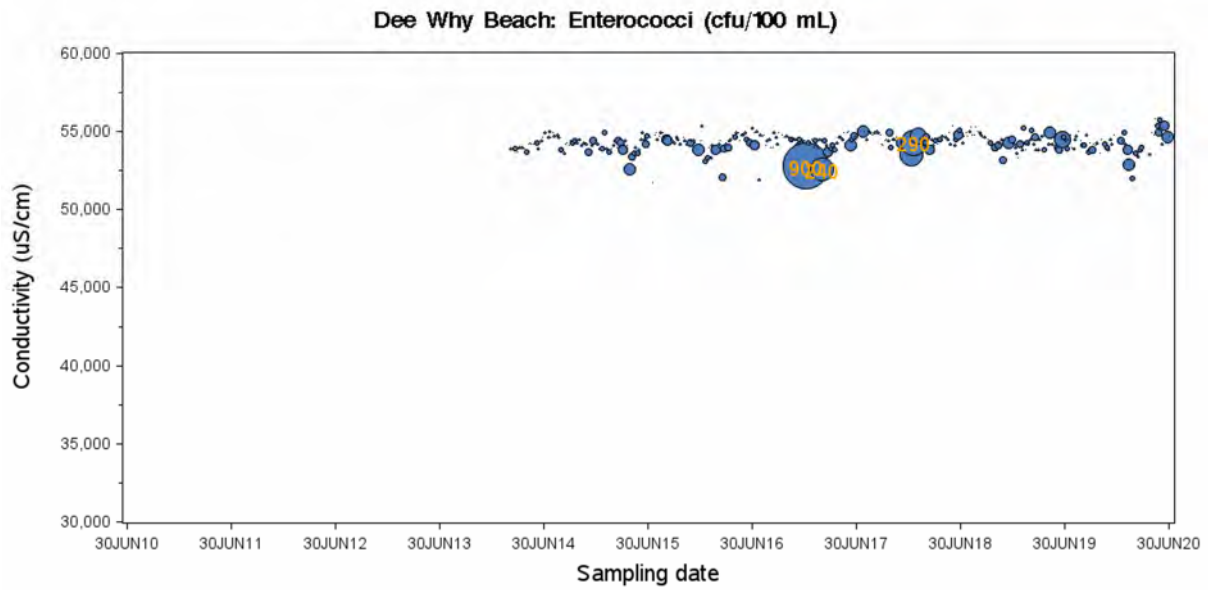


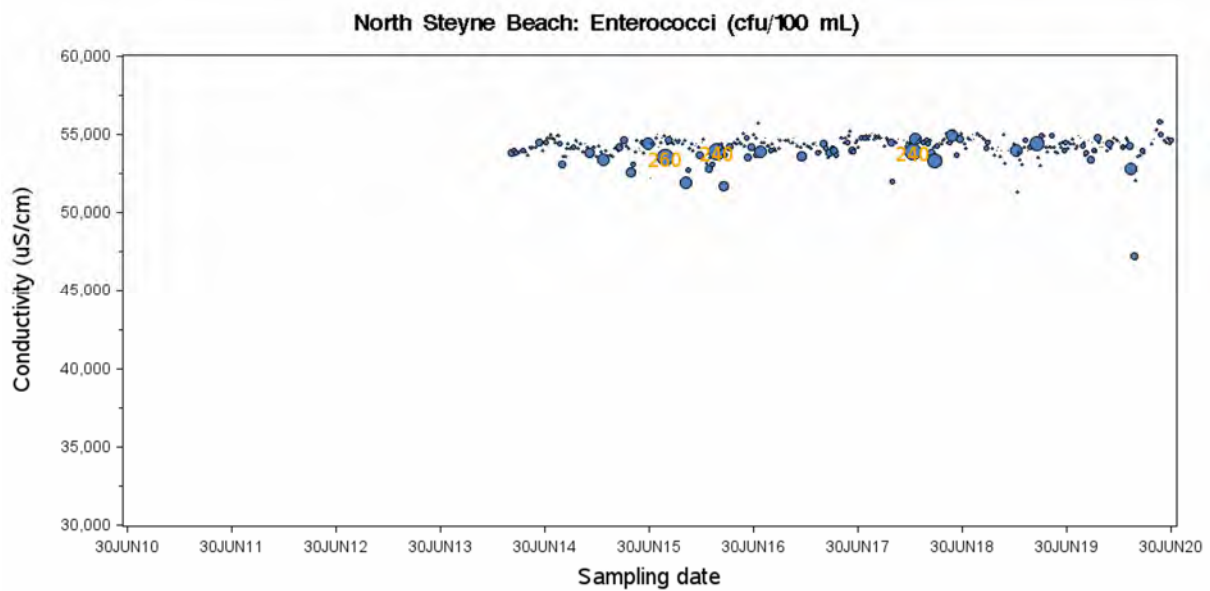
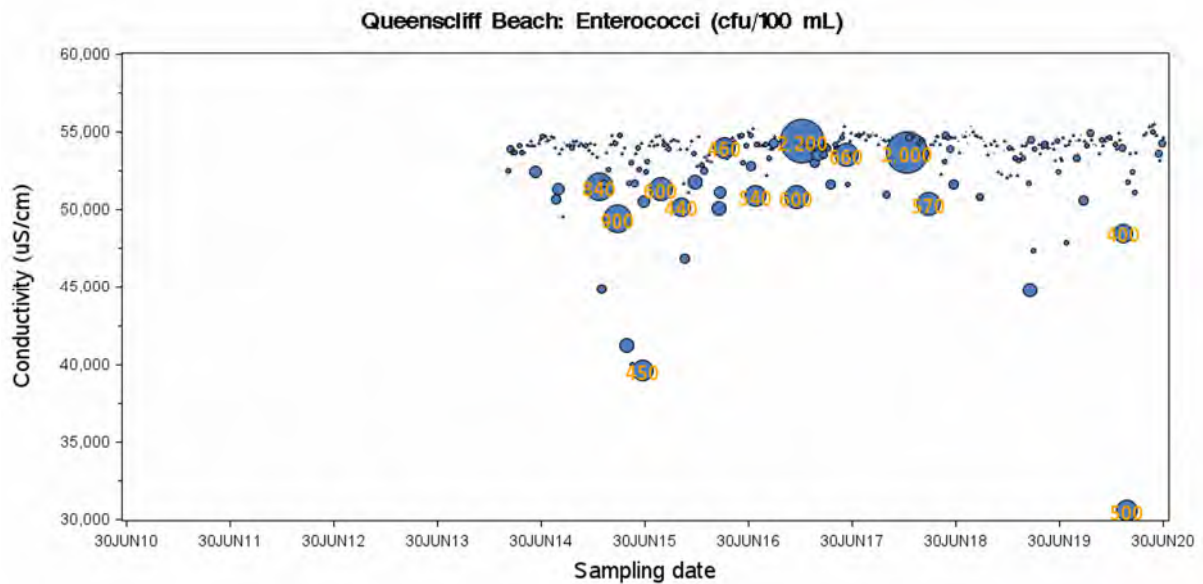
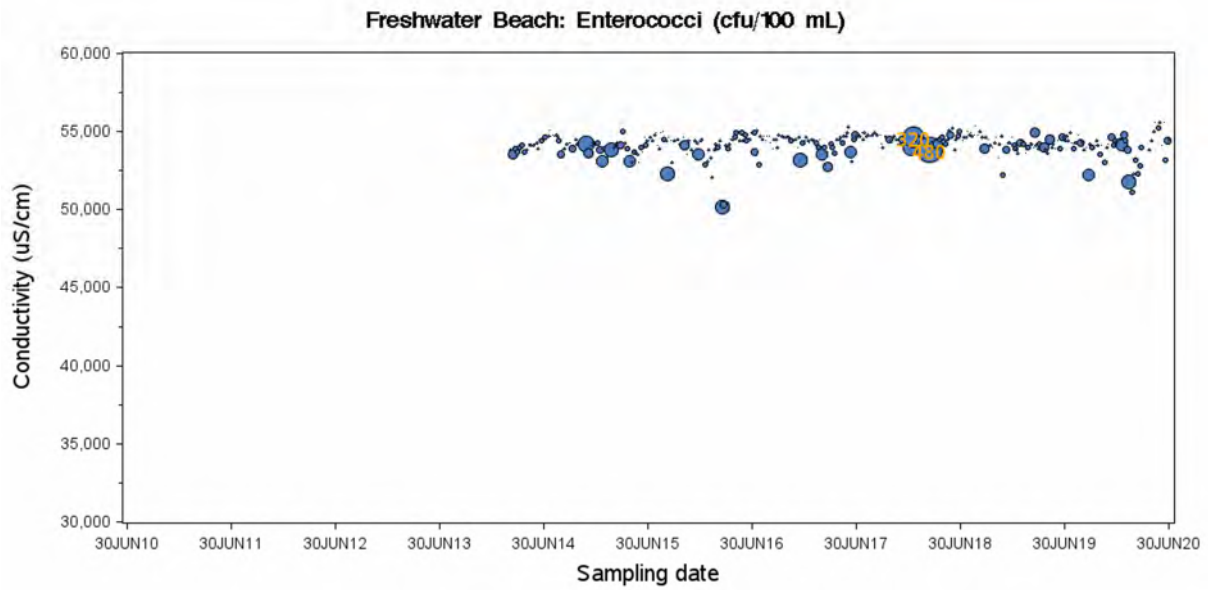


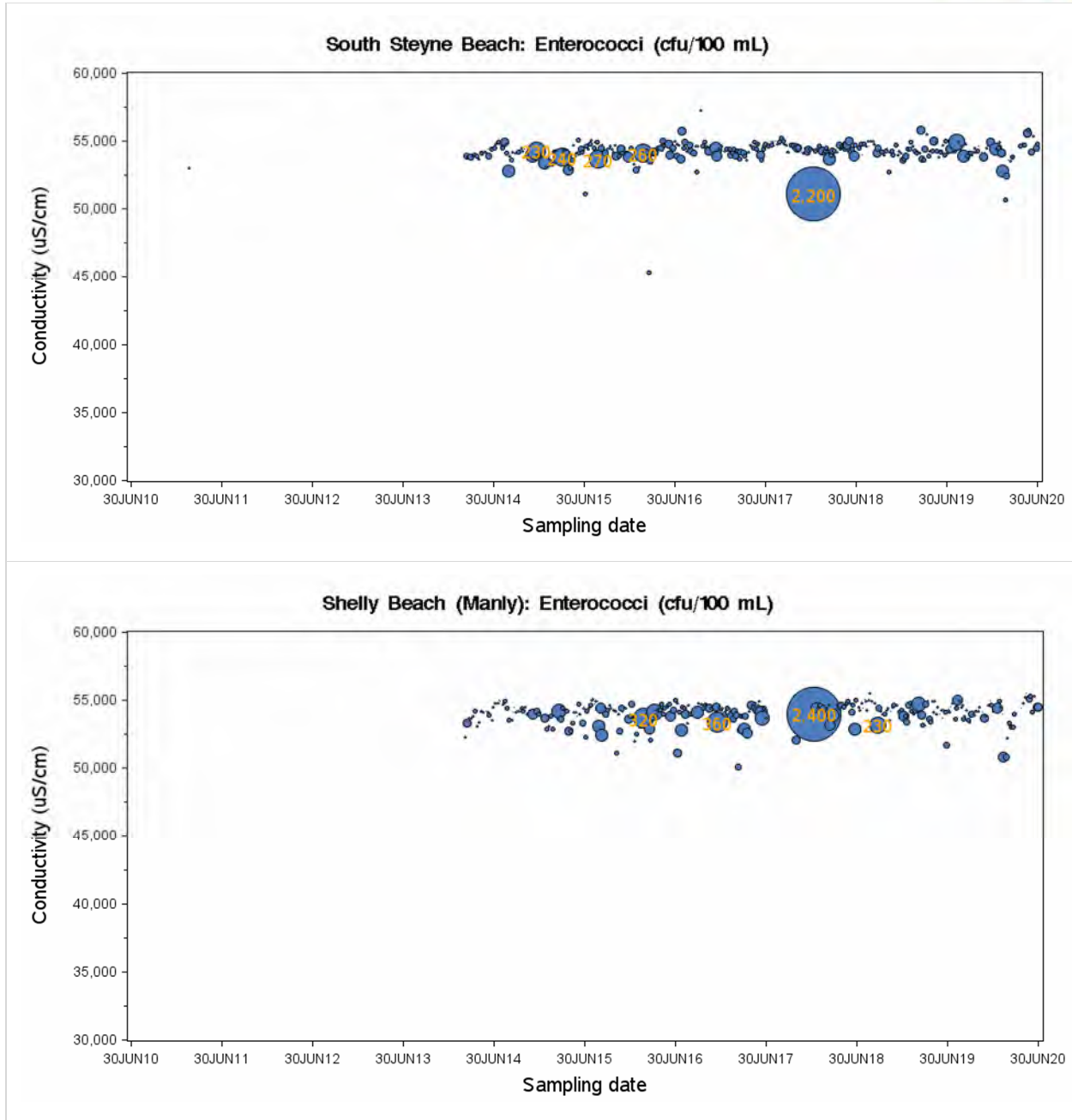
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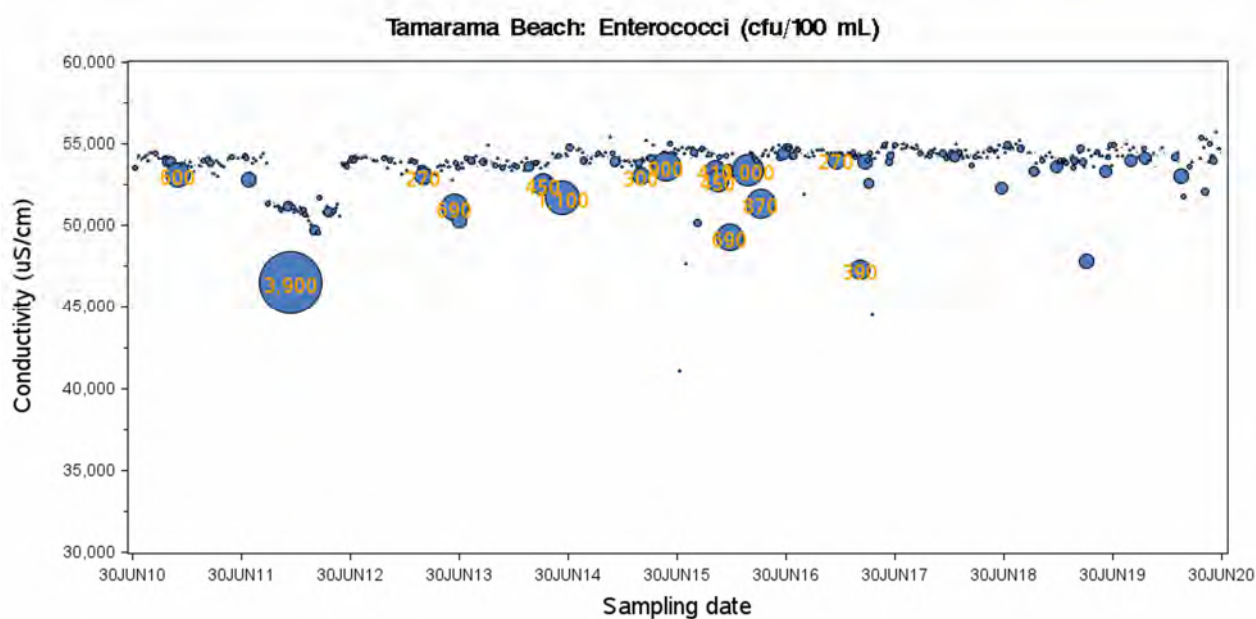


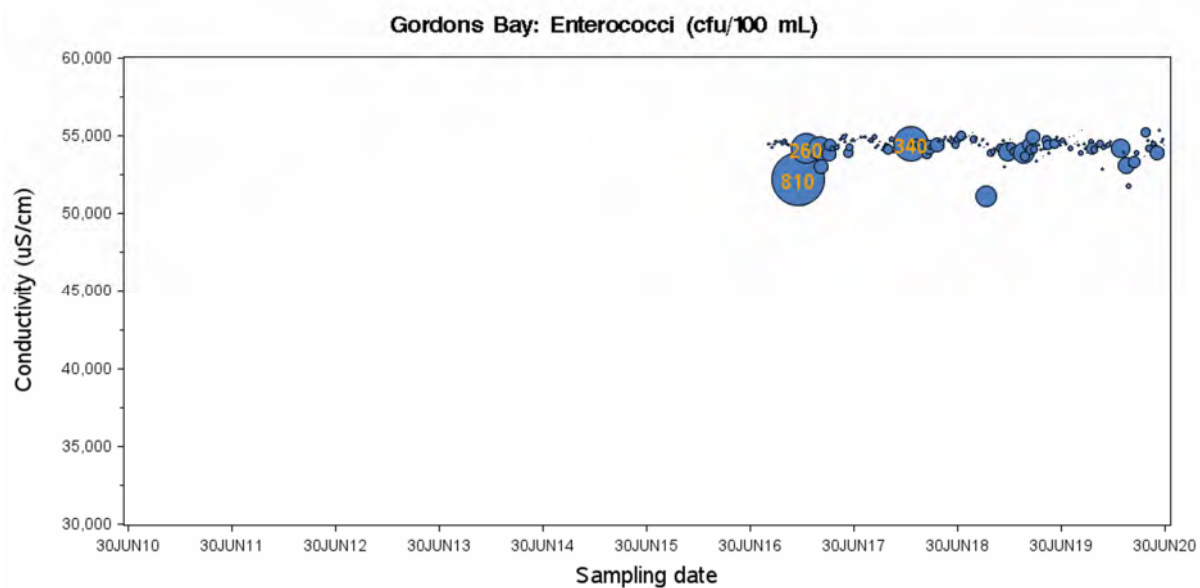
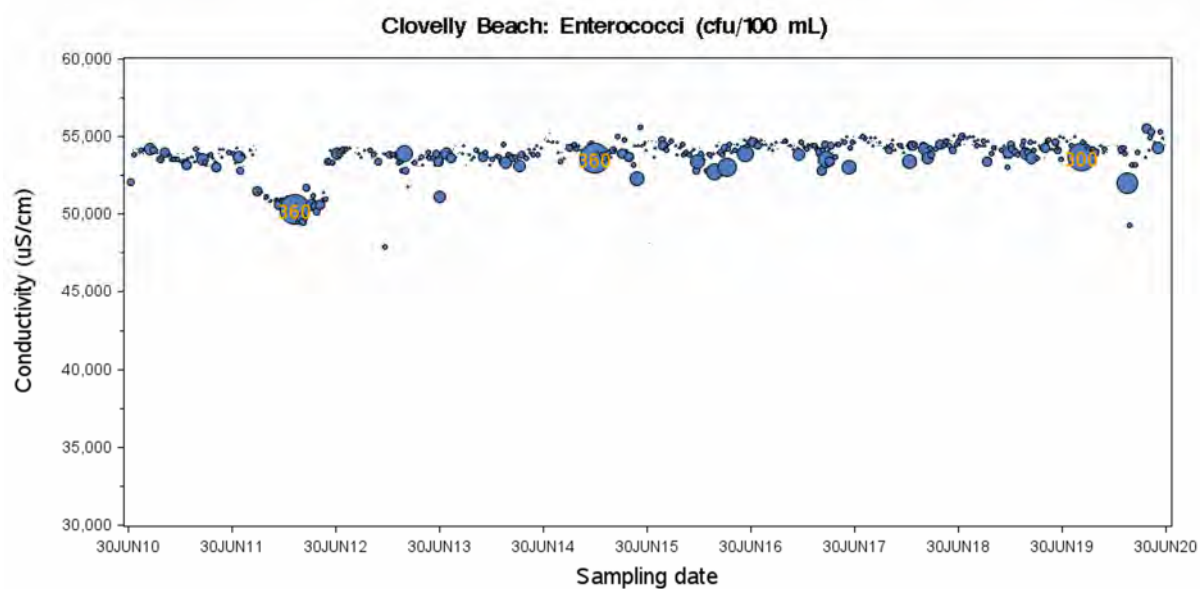
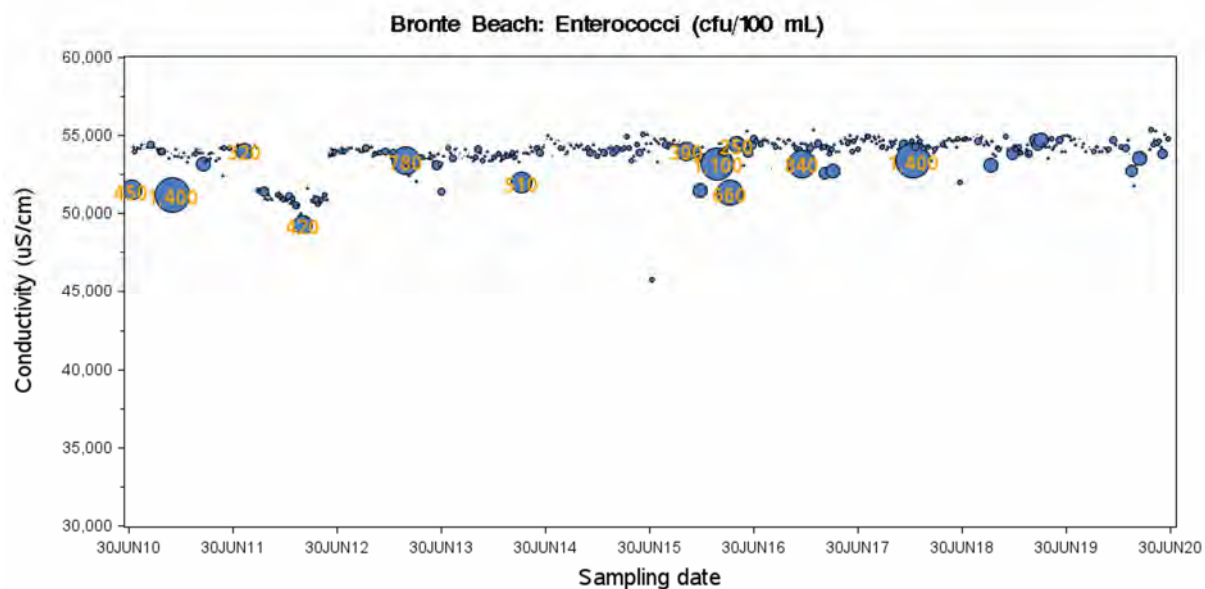


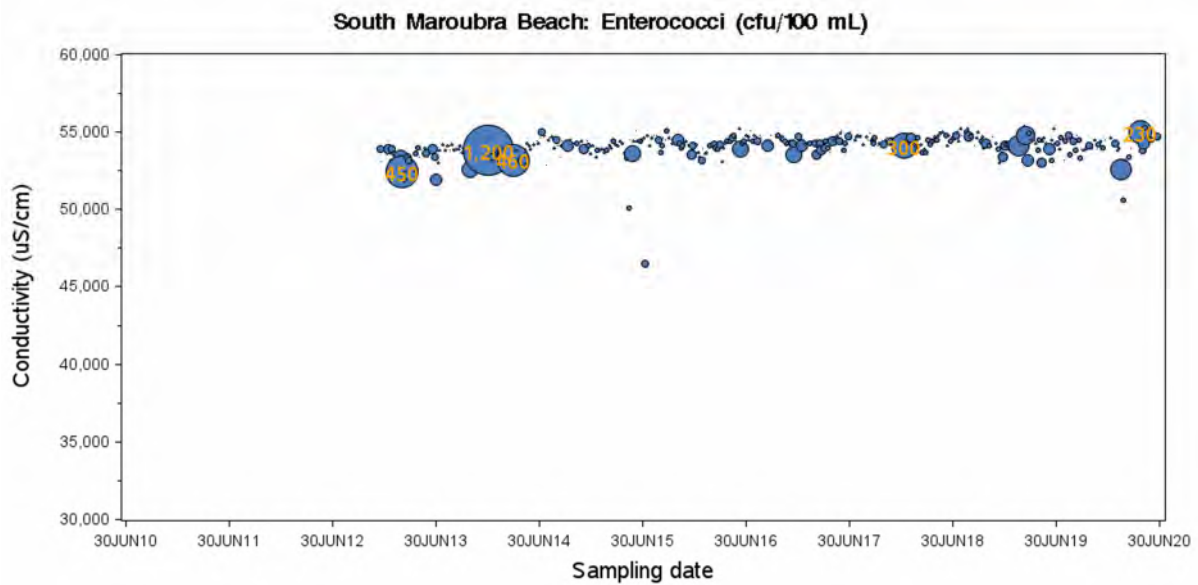
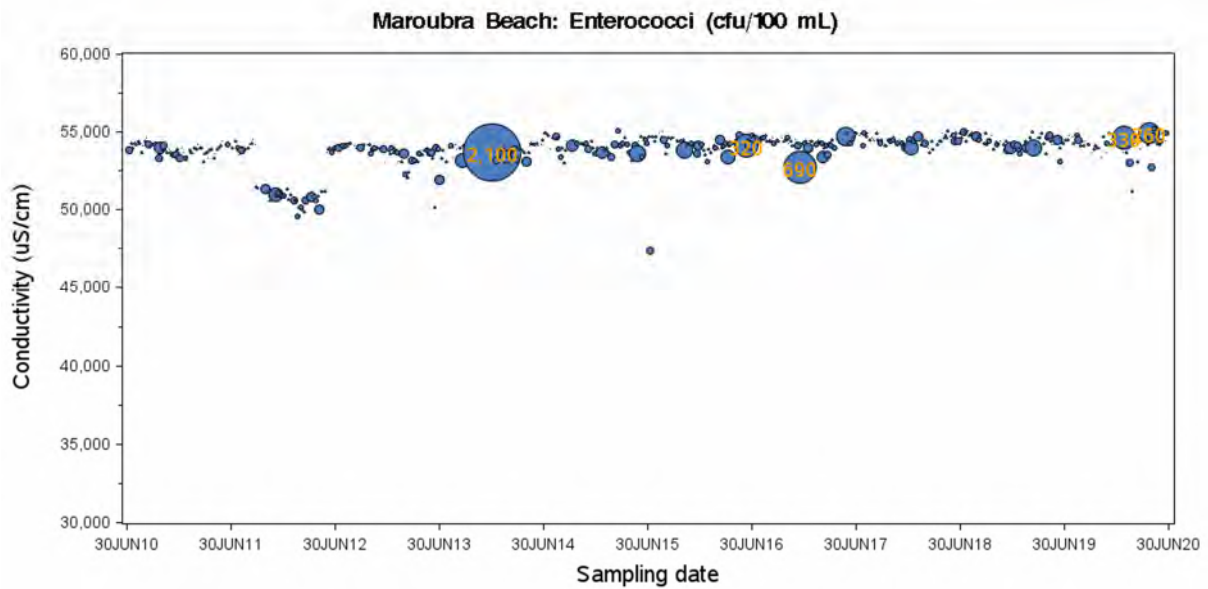
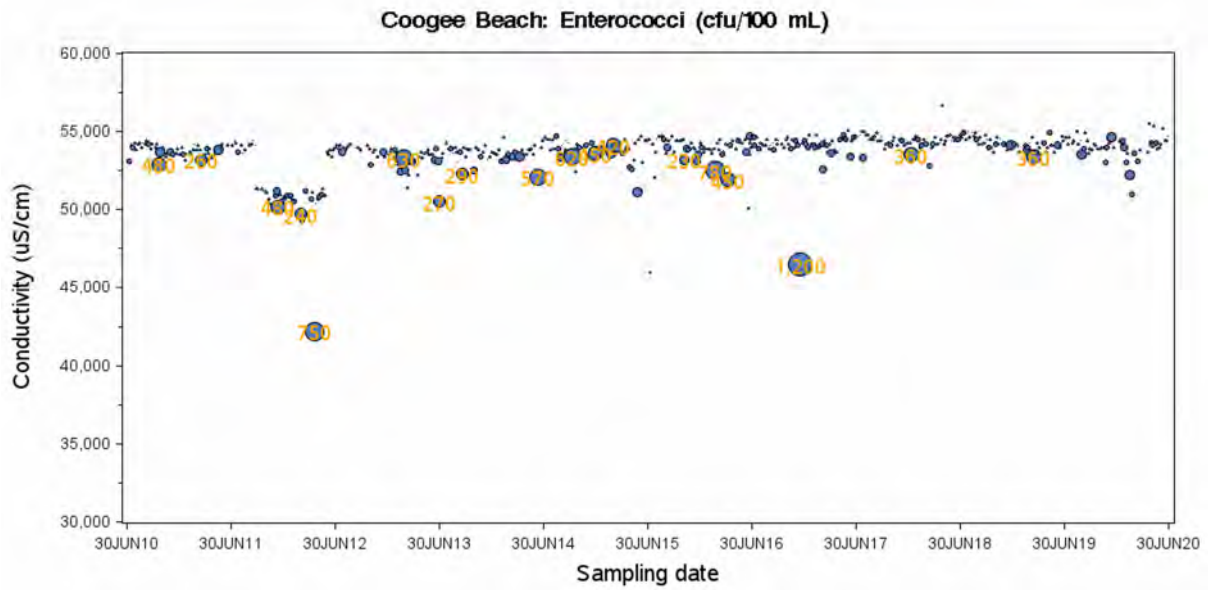


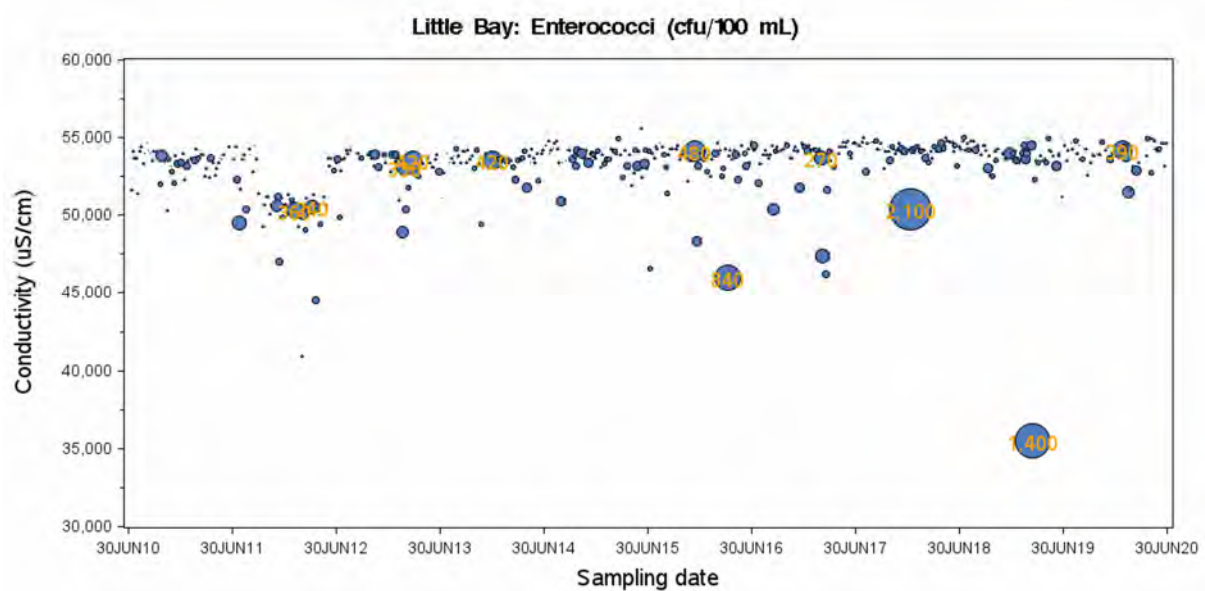
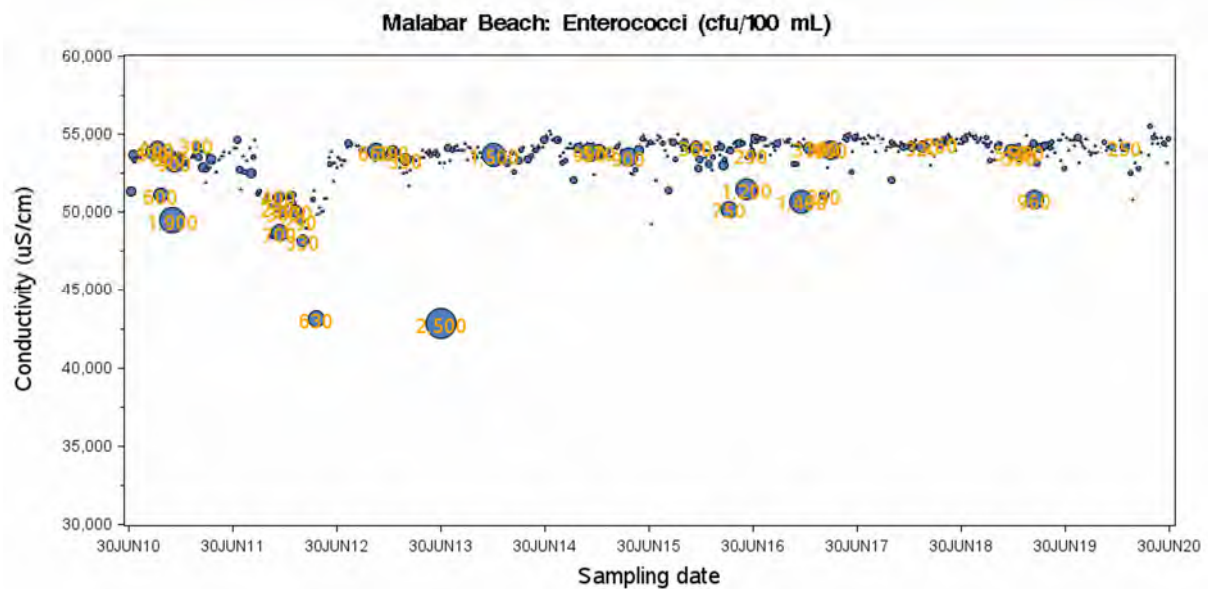
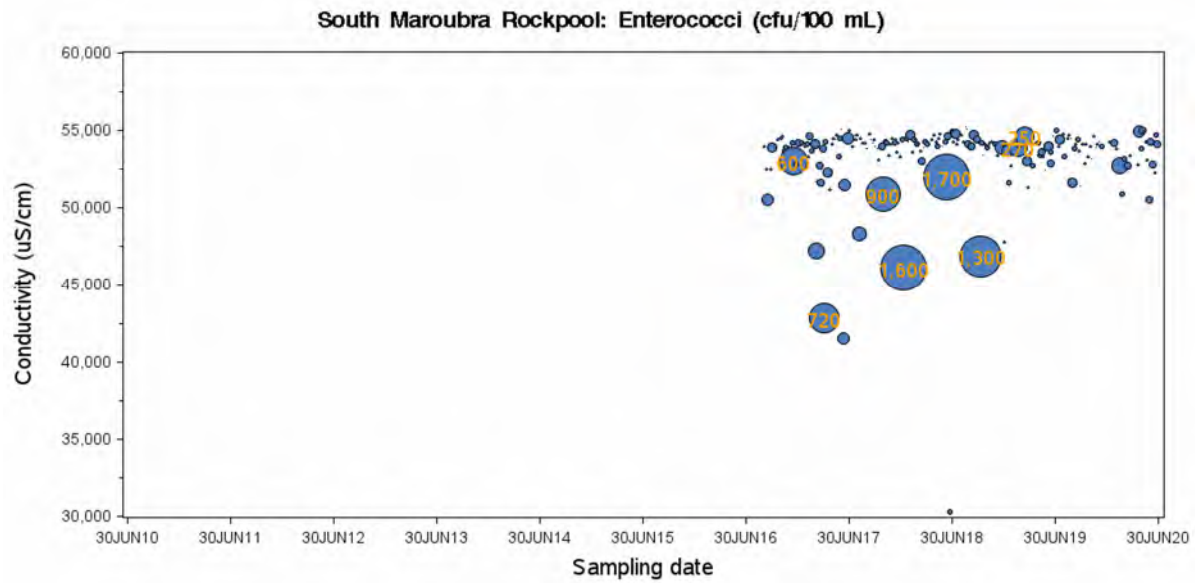


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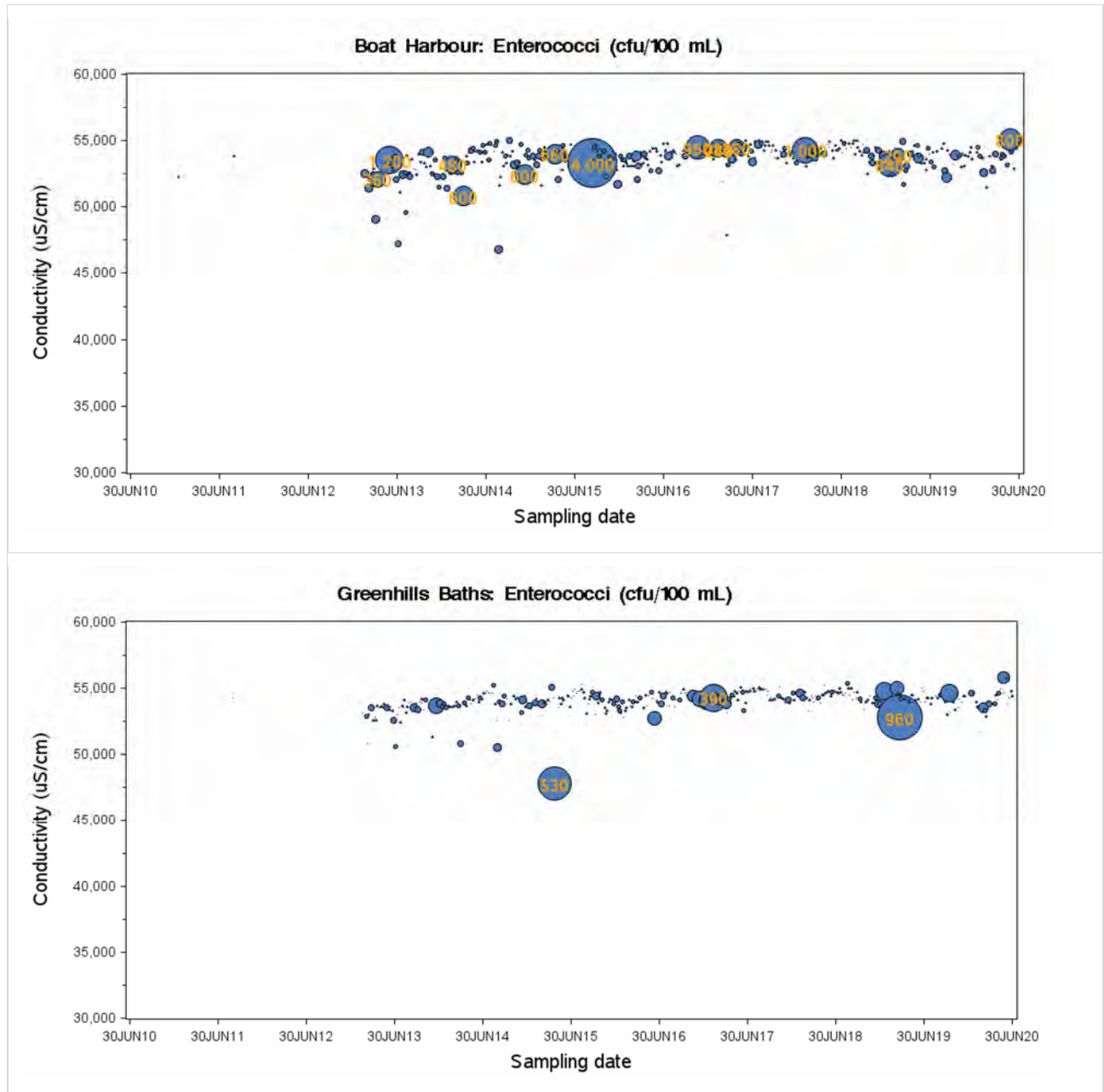


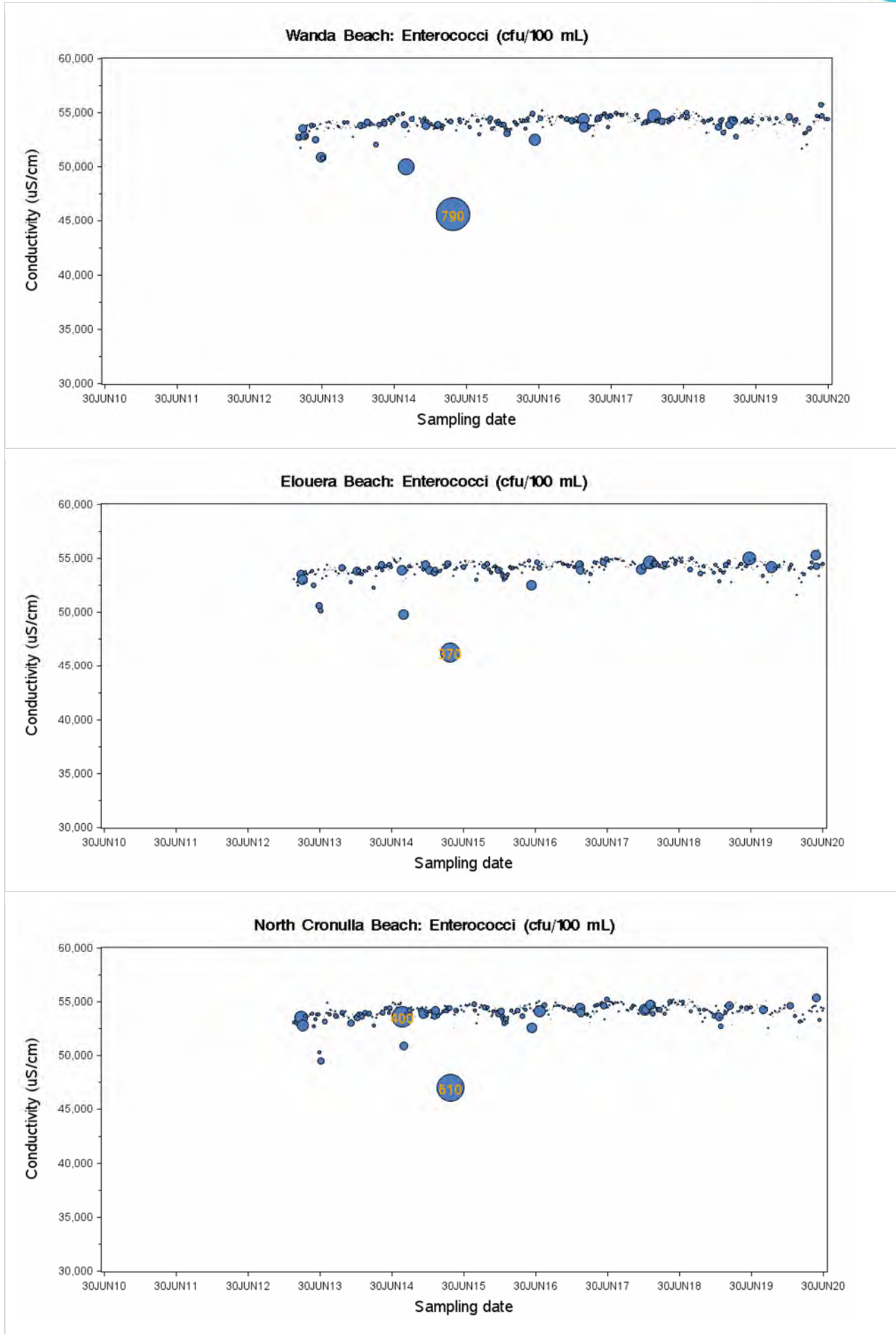


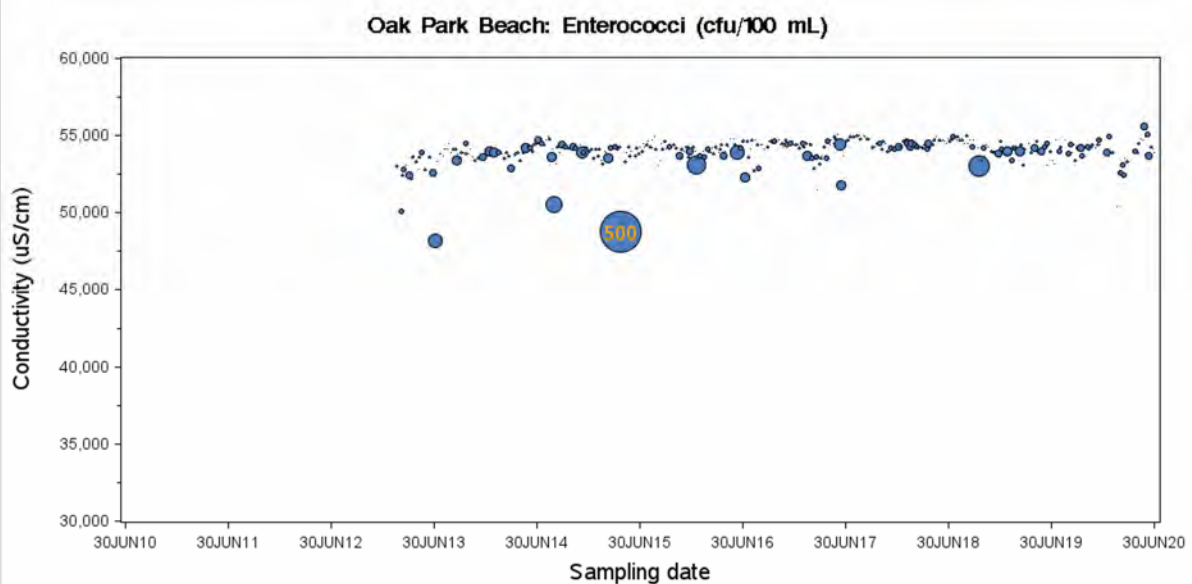
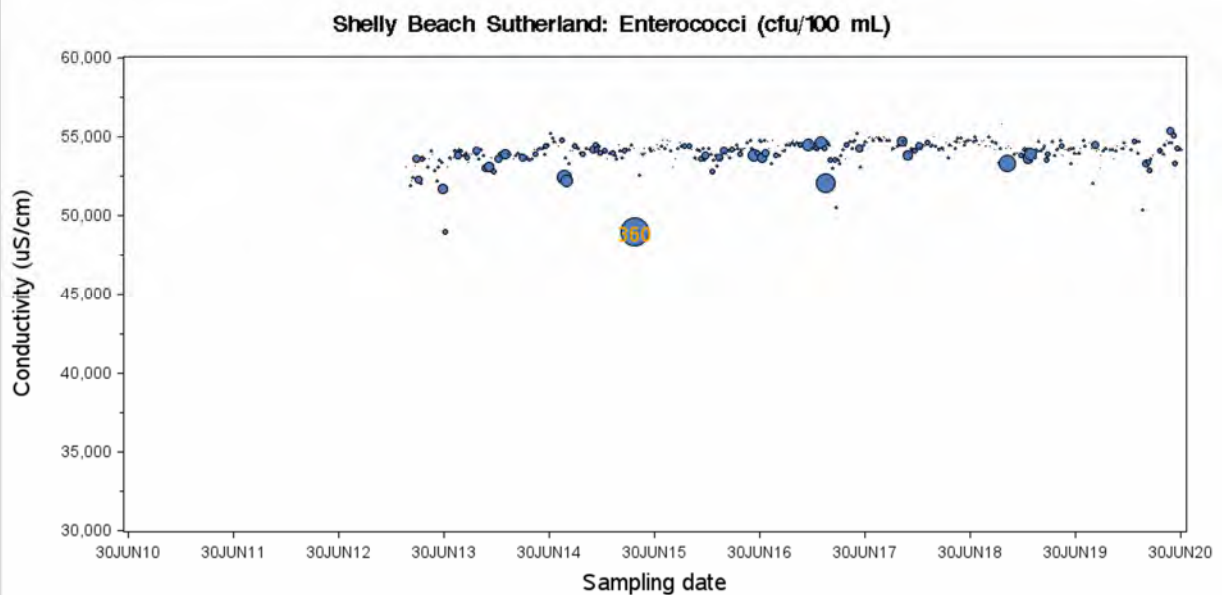
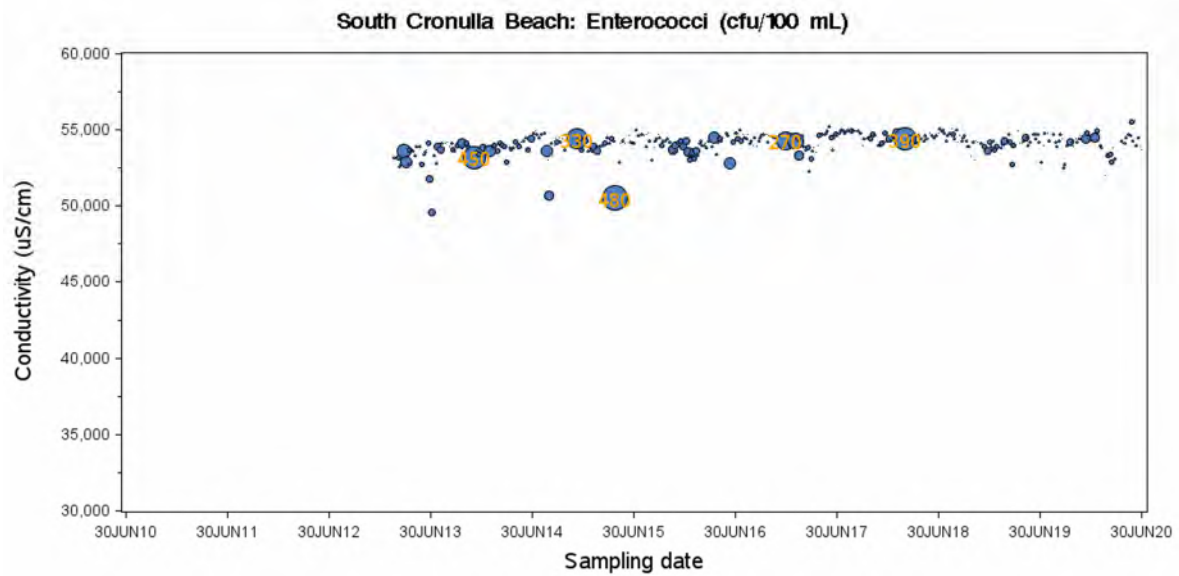




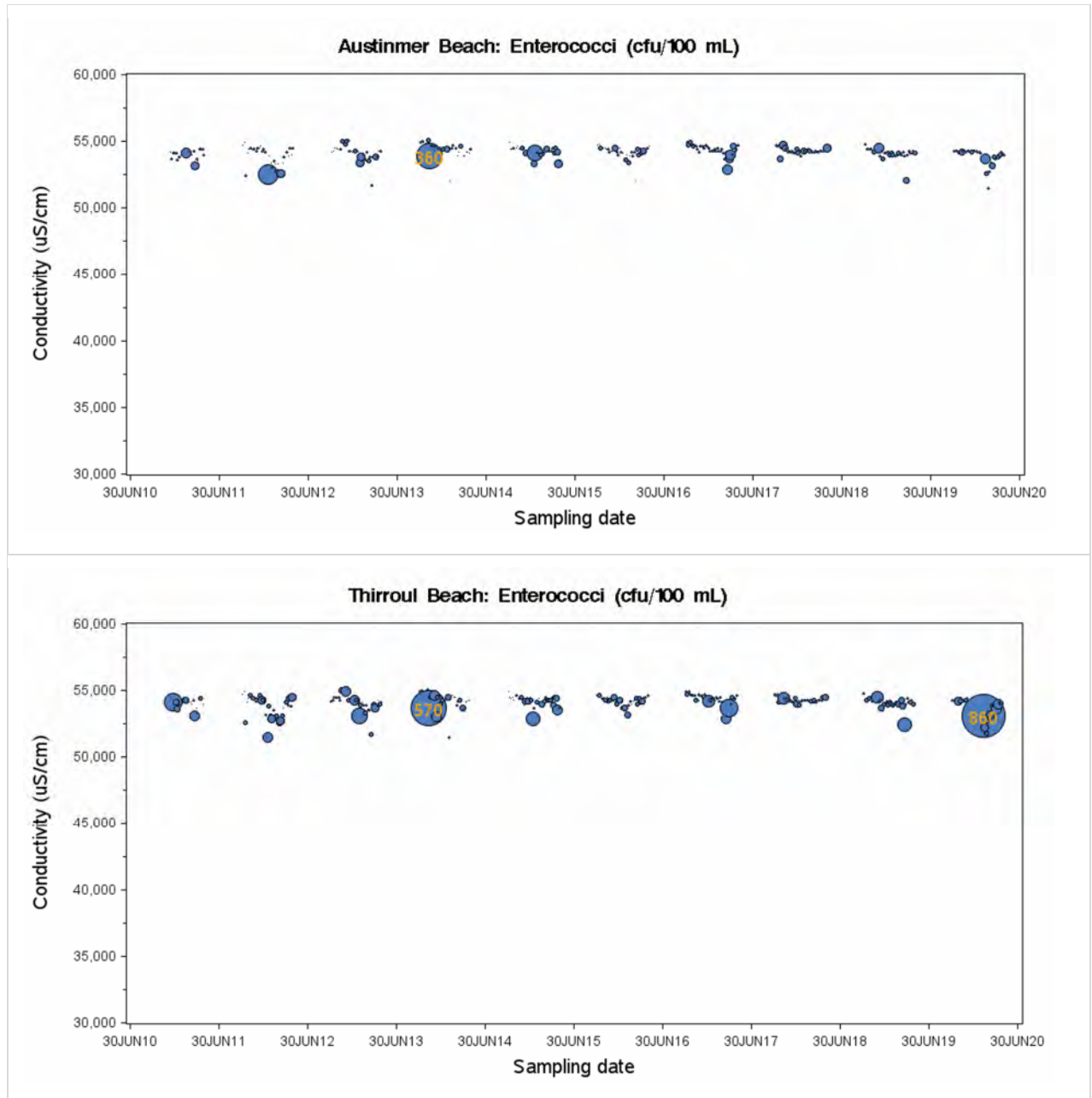
Sydney Beaches: Southern Sydney

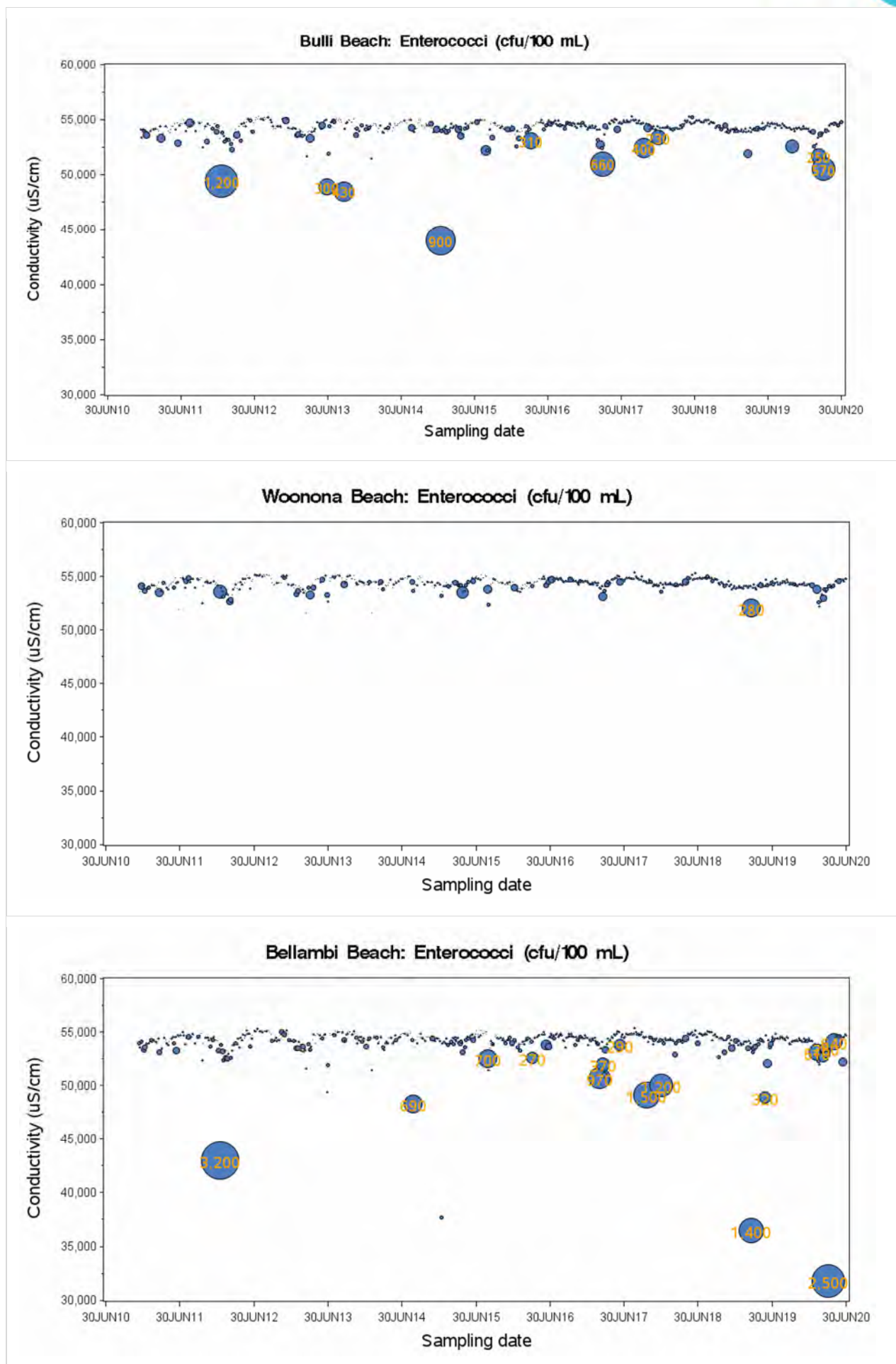


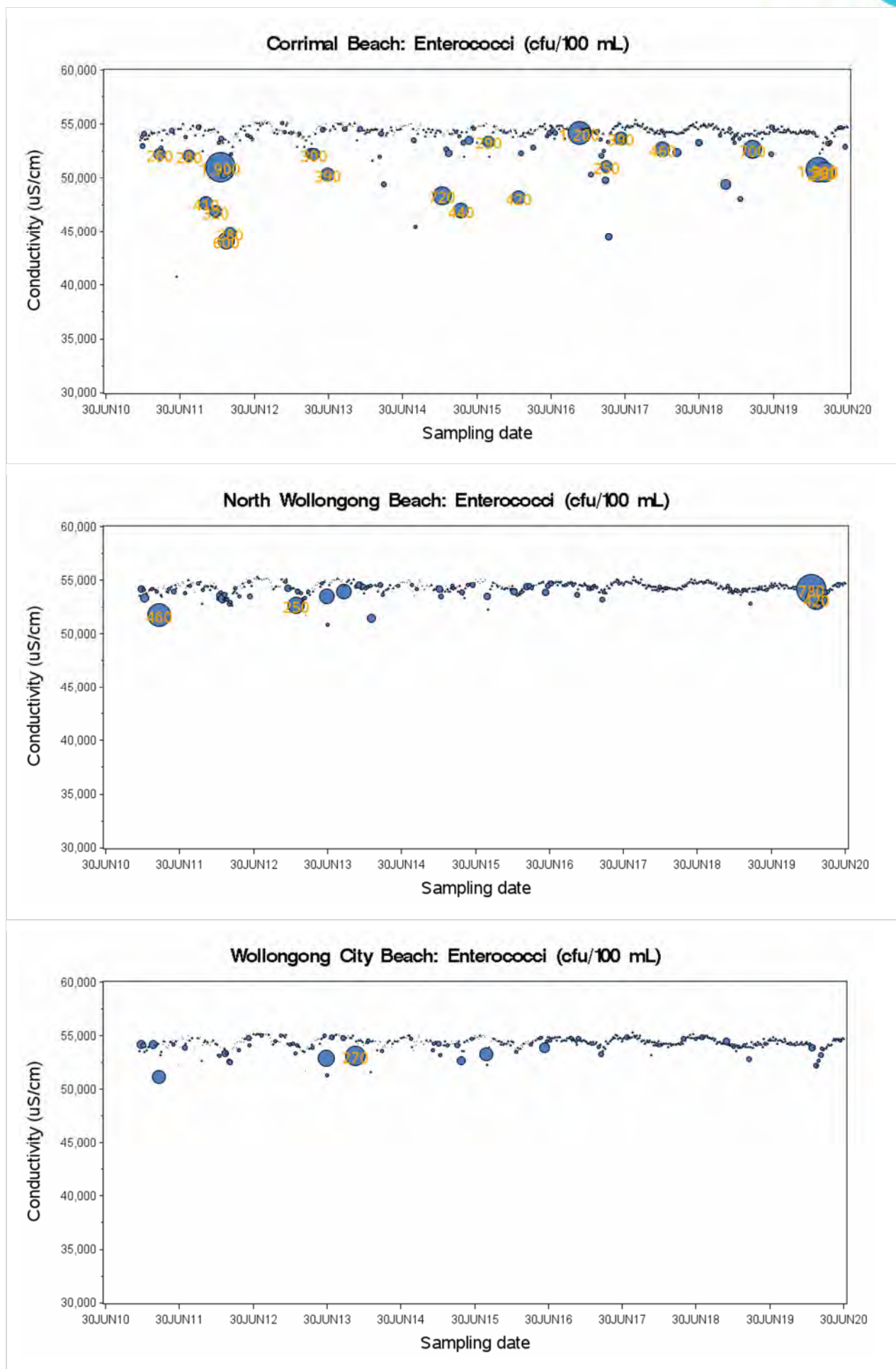


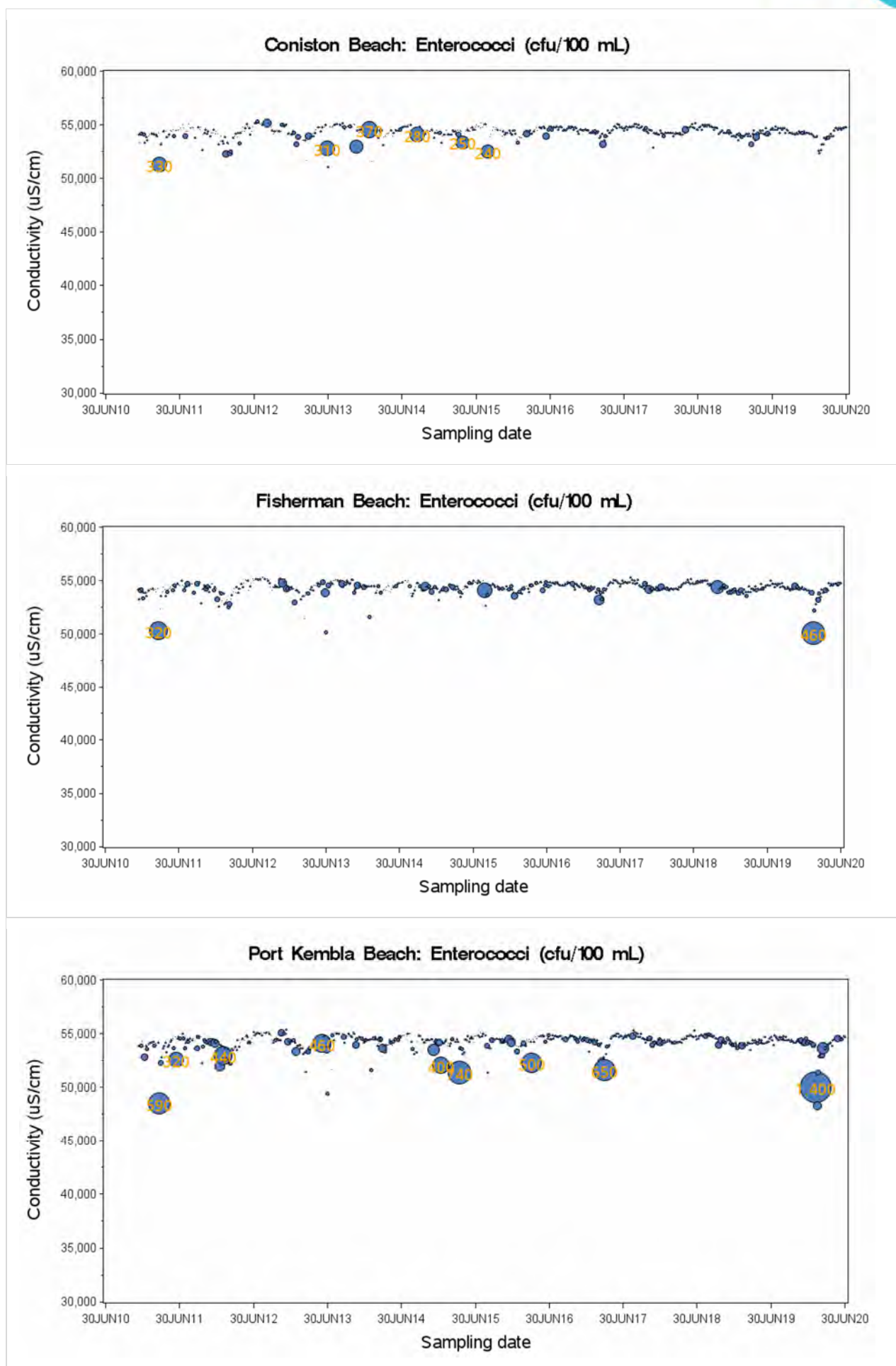


Illawarra Beaches: Wollongong

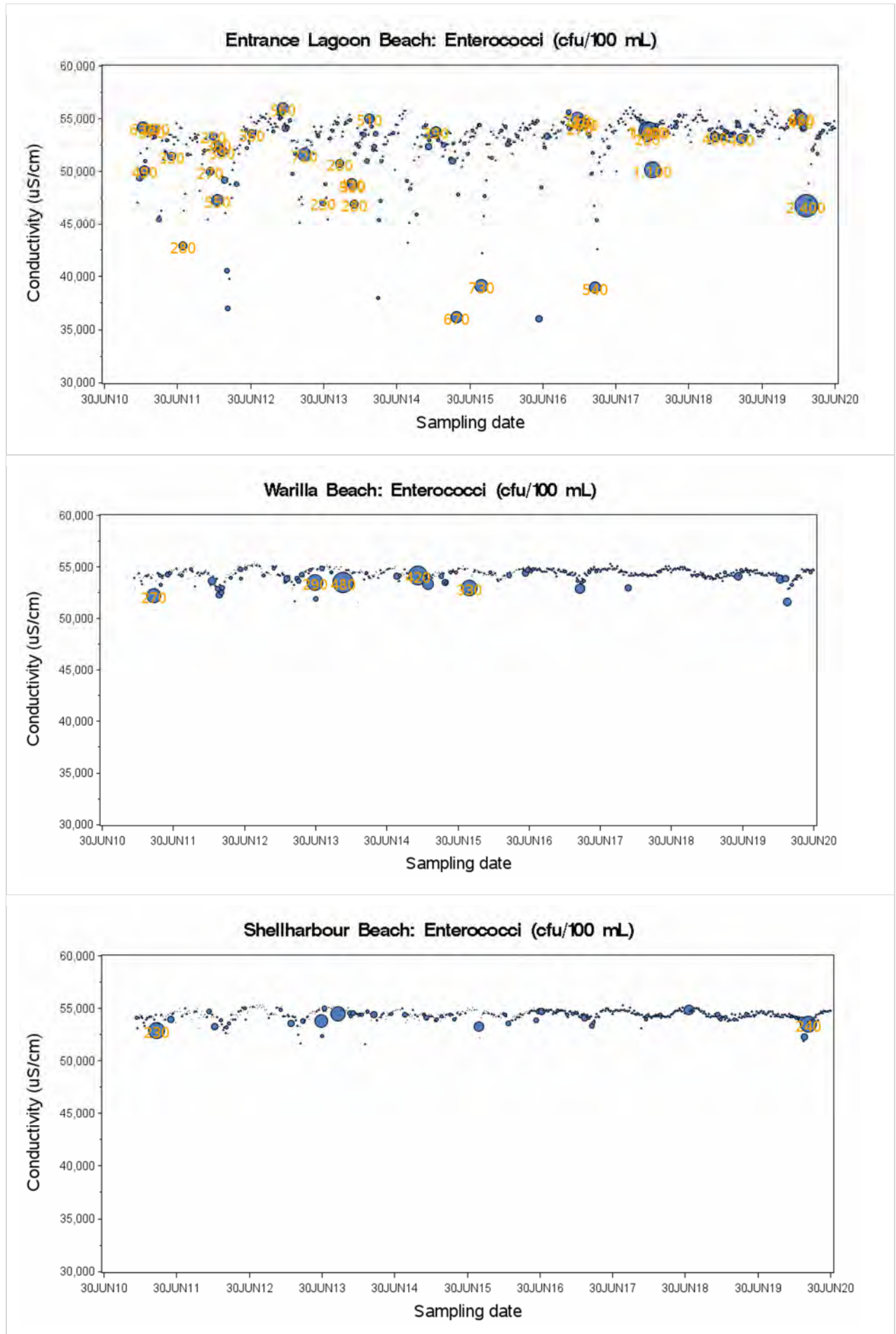


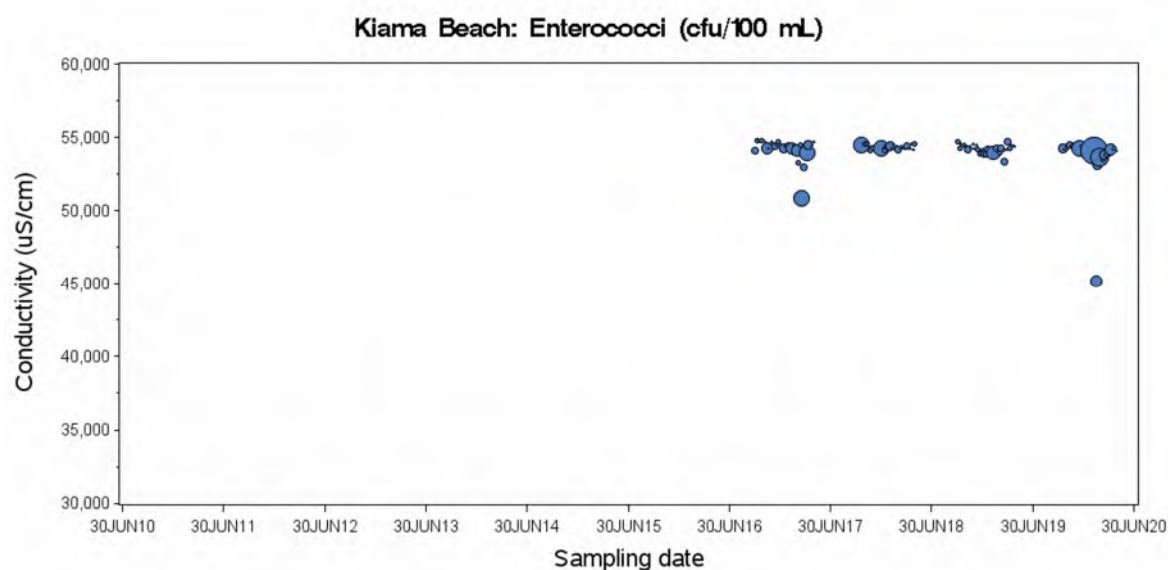
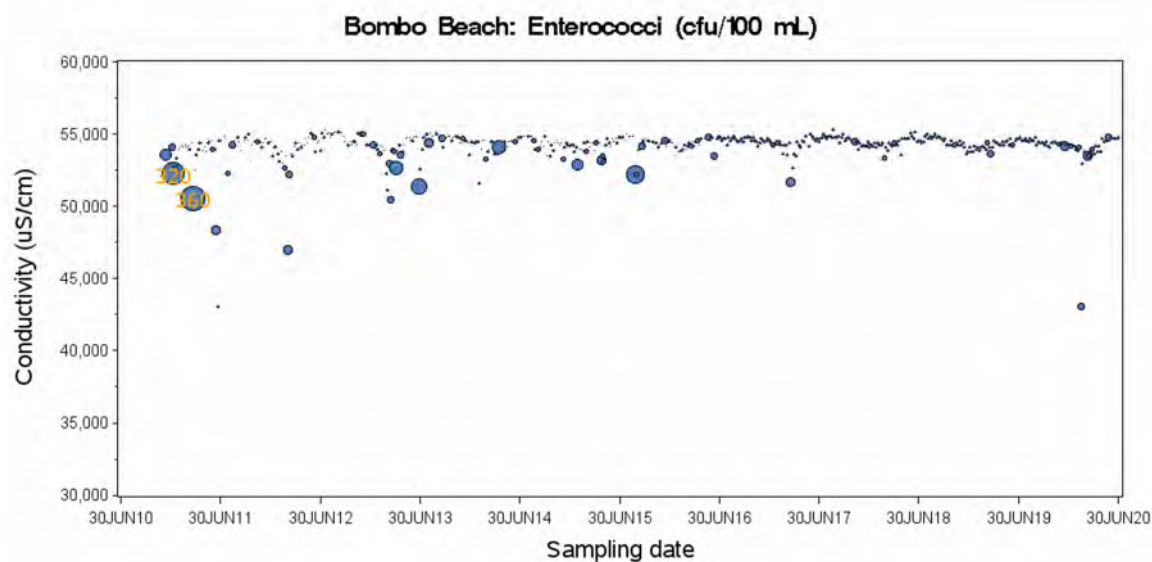
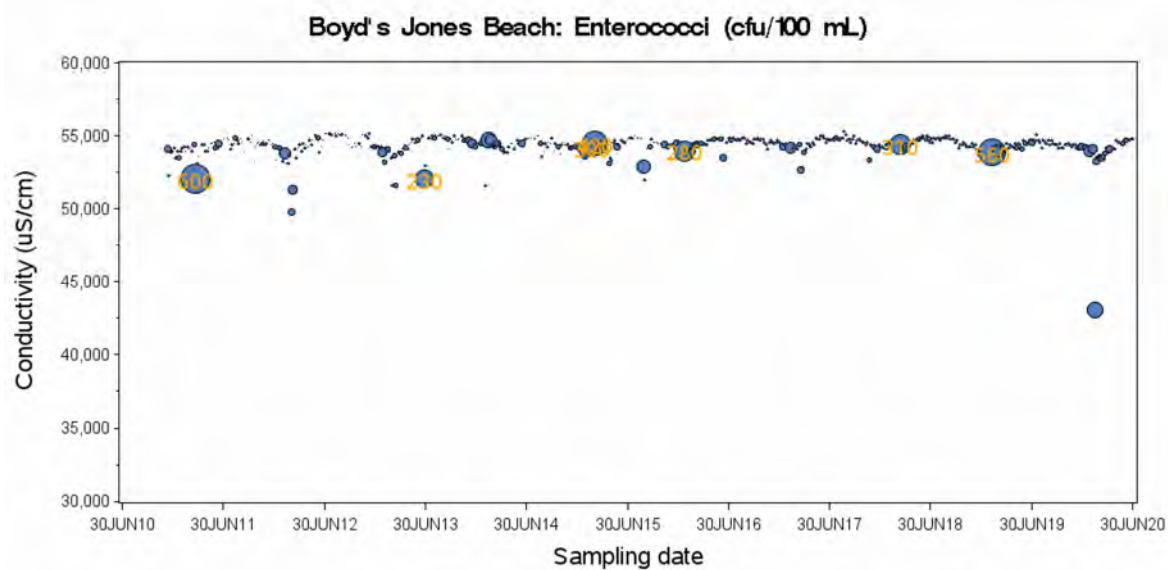




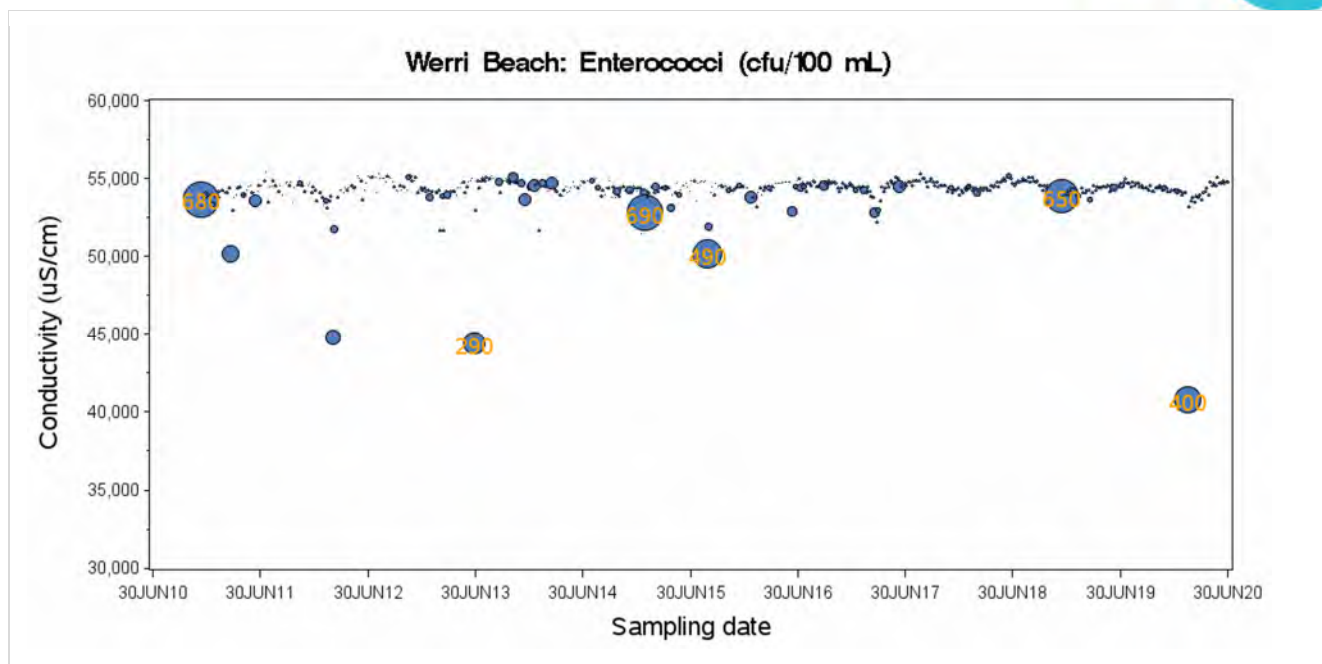


Illawarra Beaches: Shellharbour

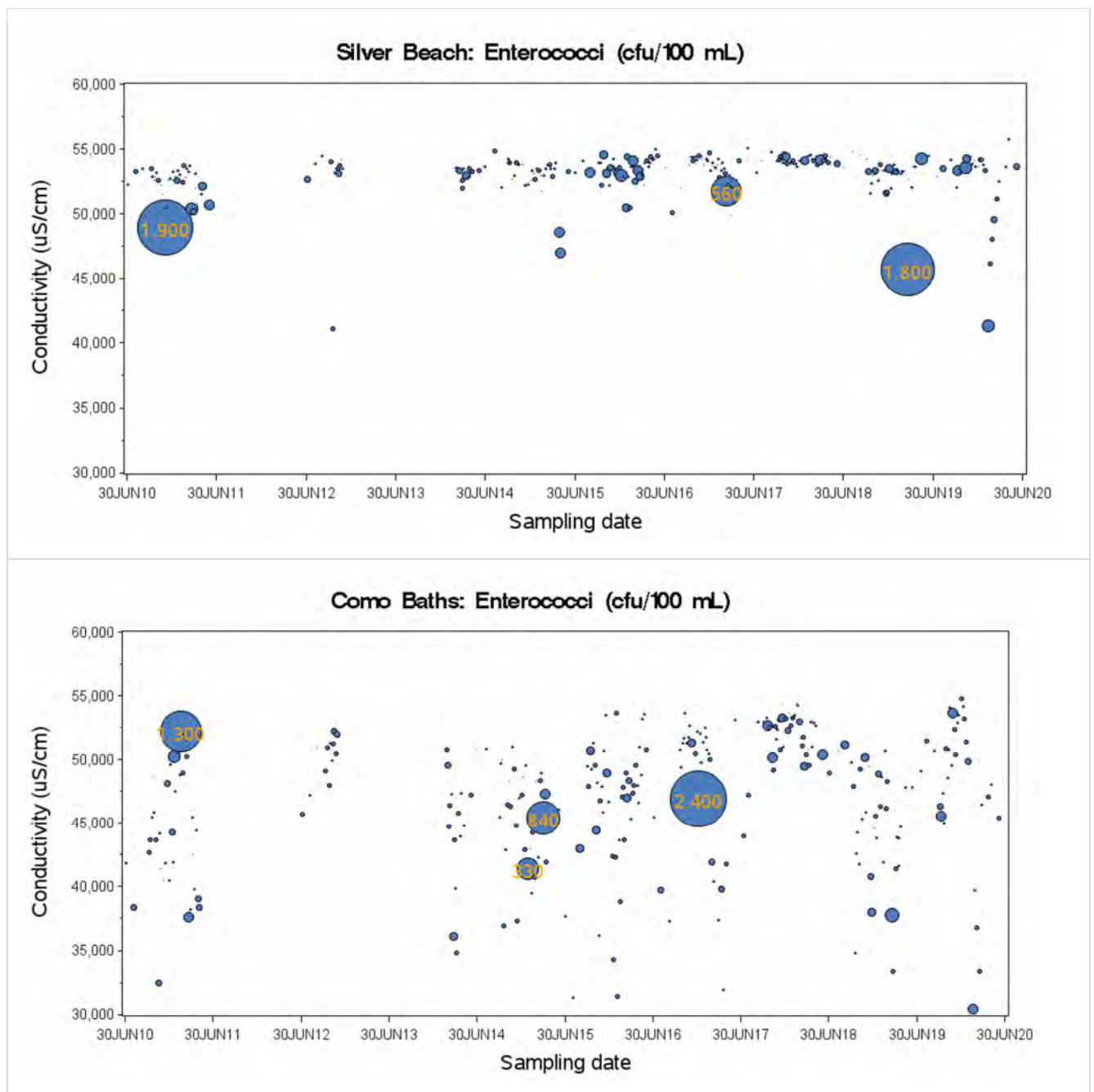


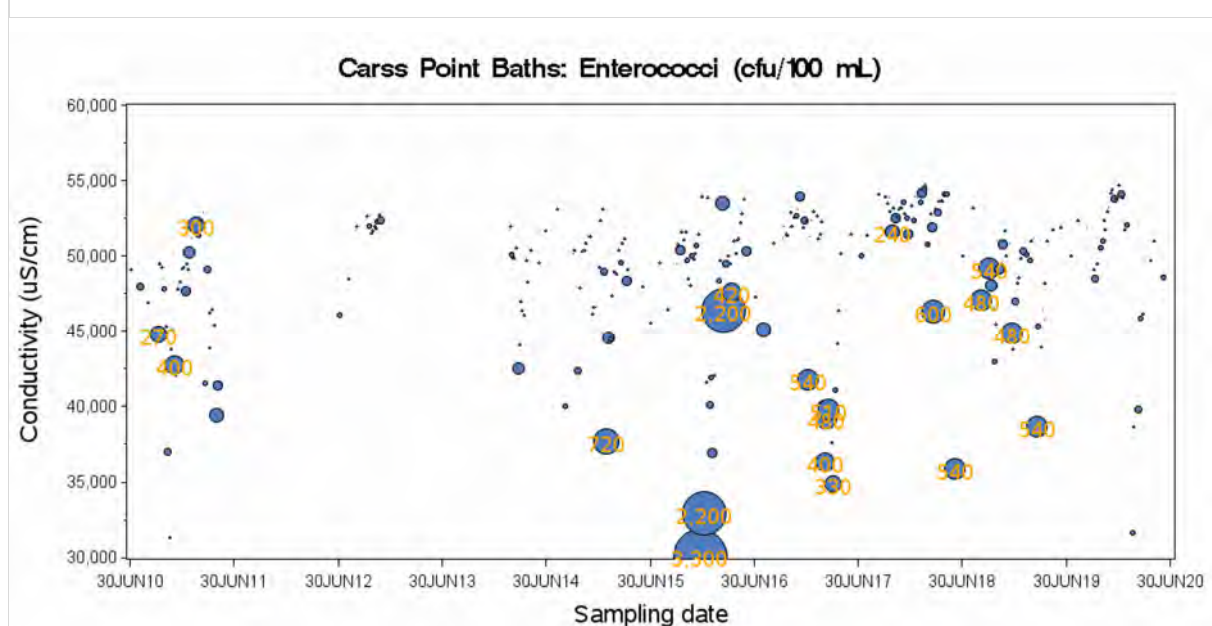
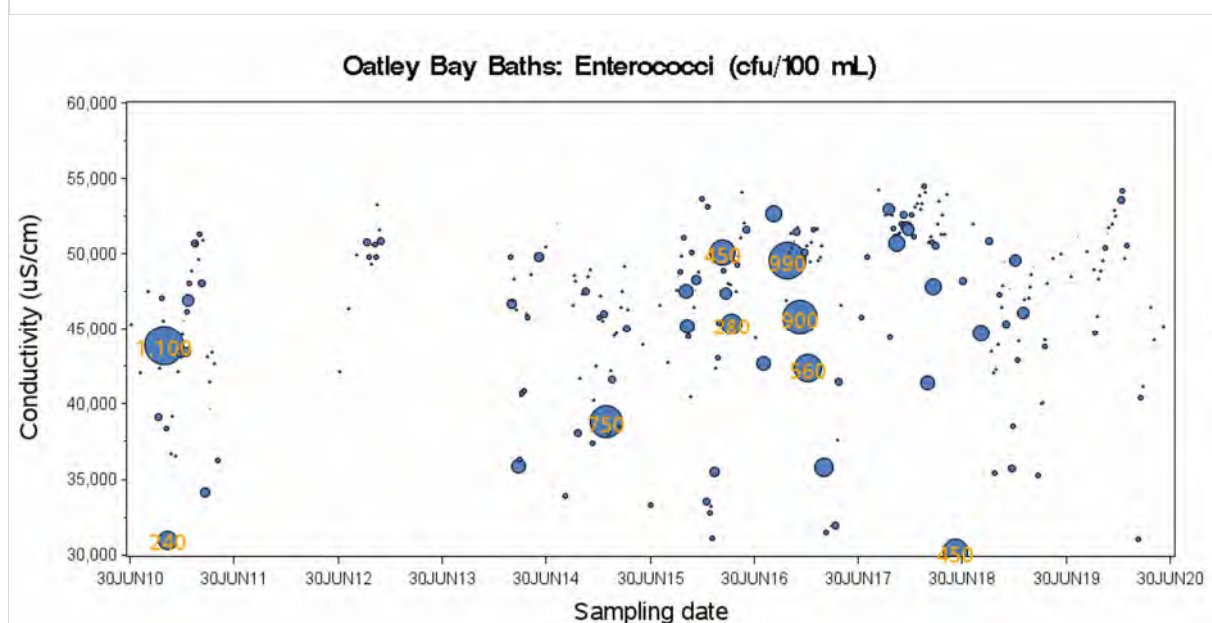
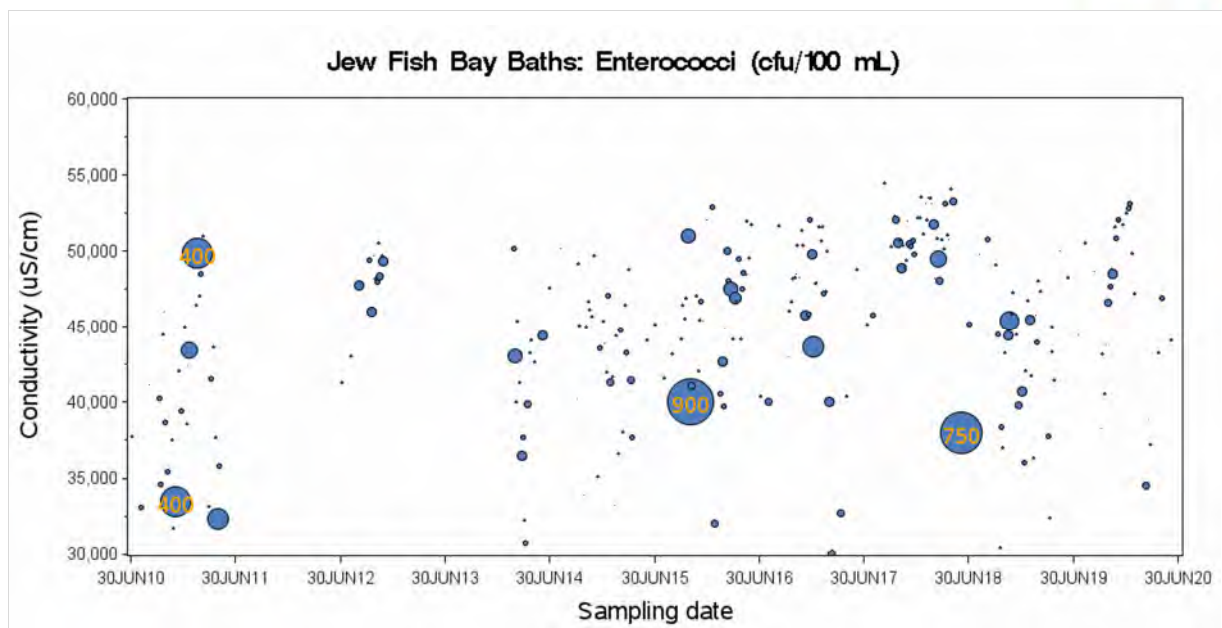


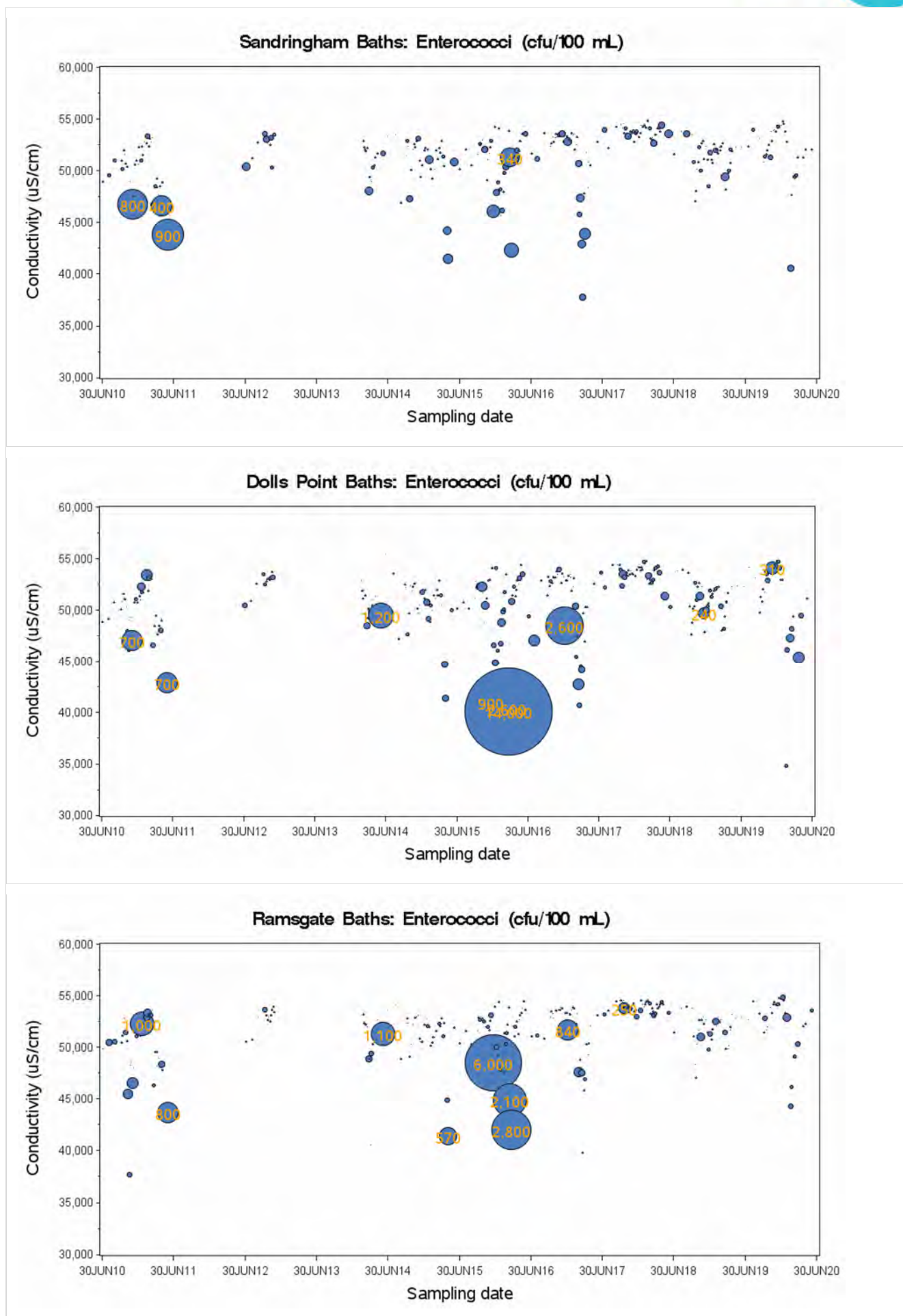
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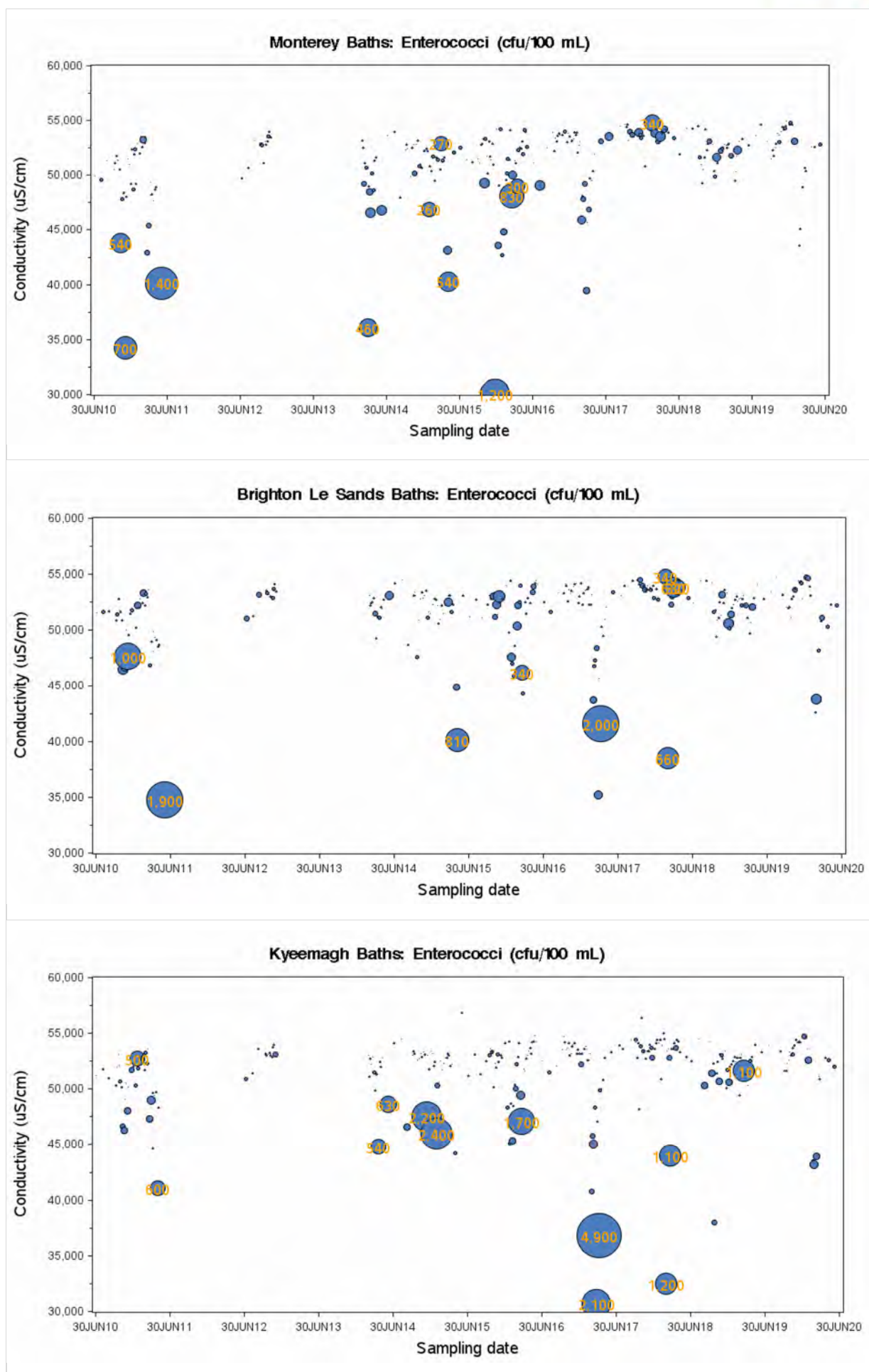


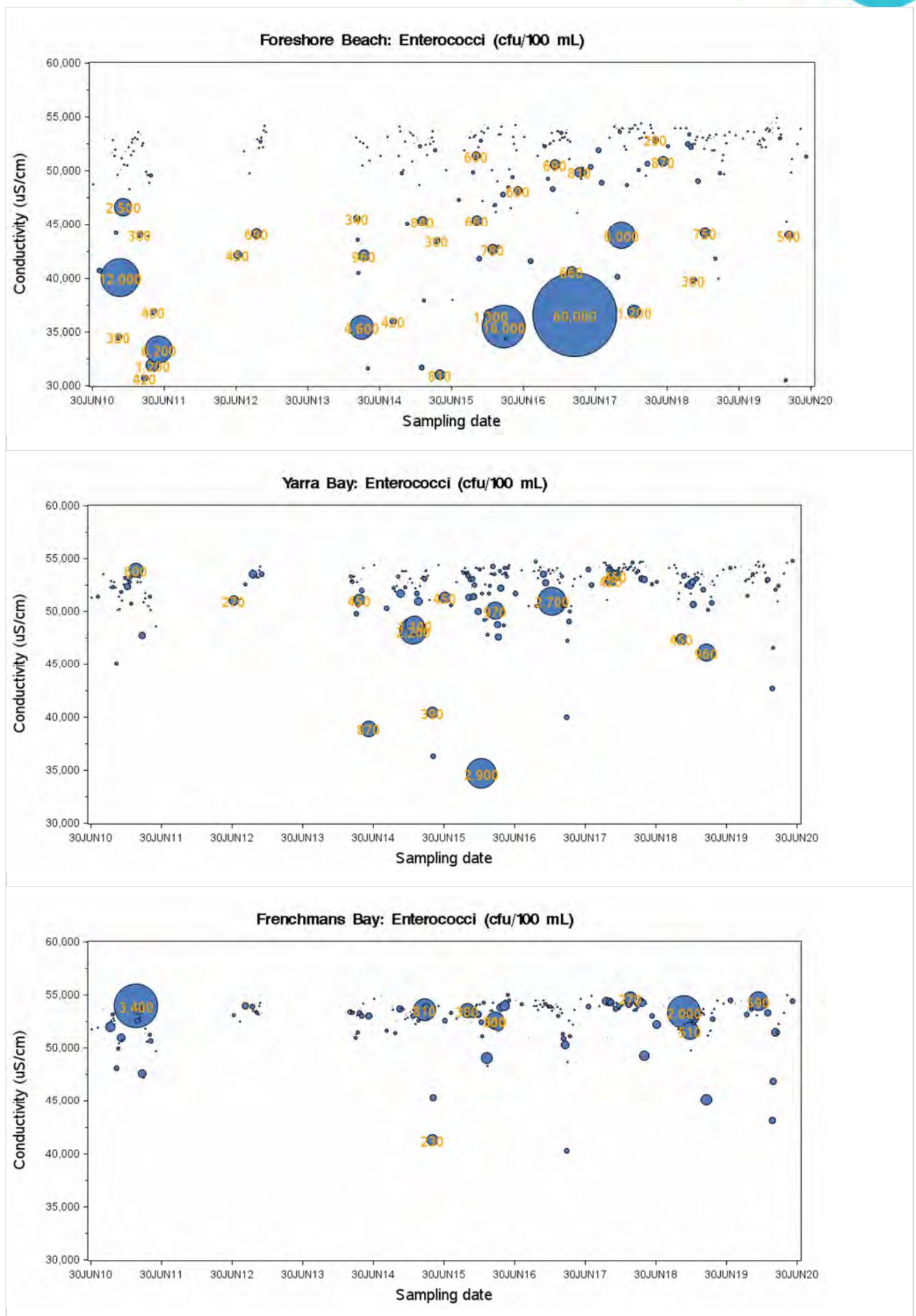
Sydney Harbour and Estuaries: Botany Bay and Georges River

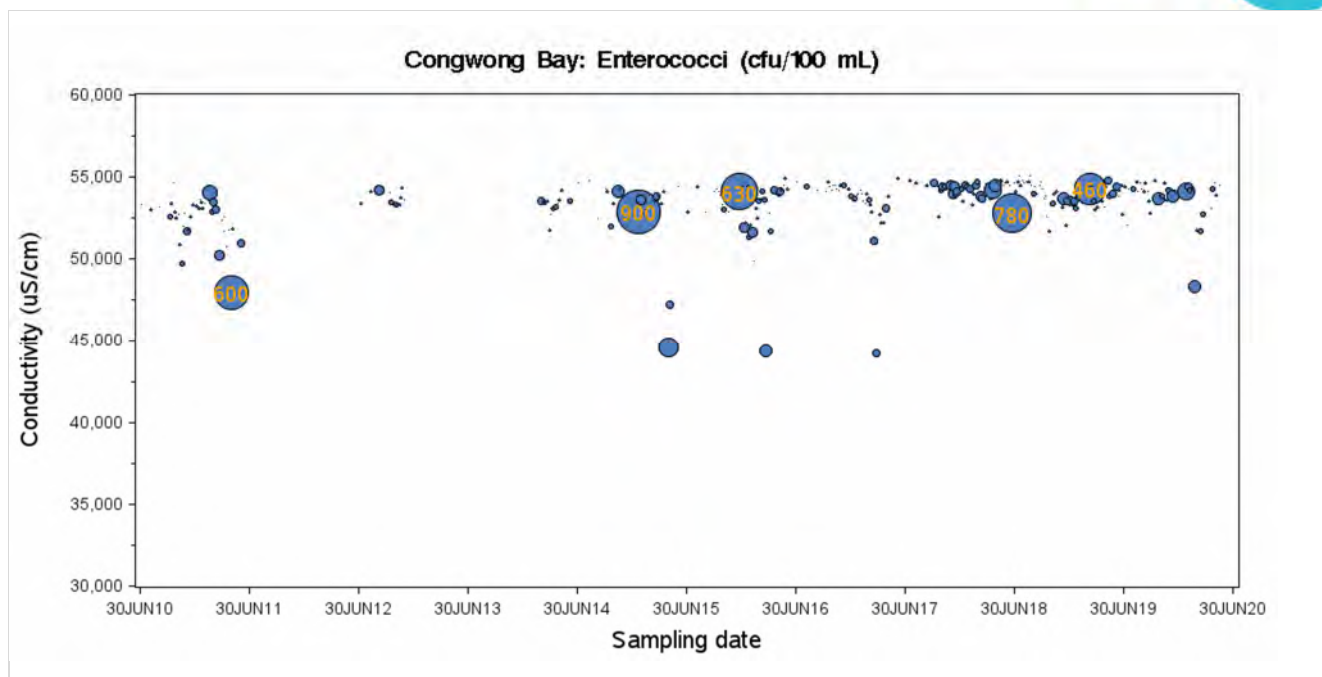




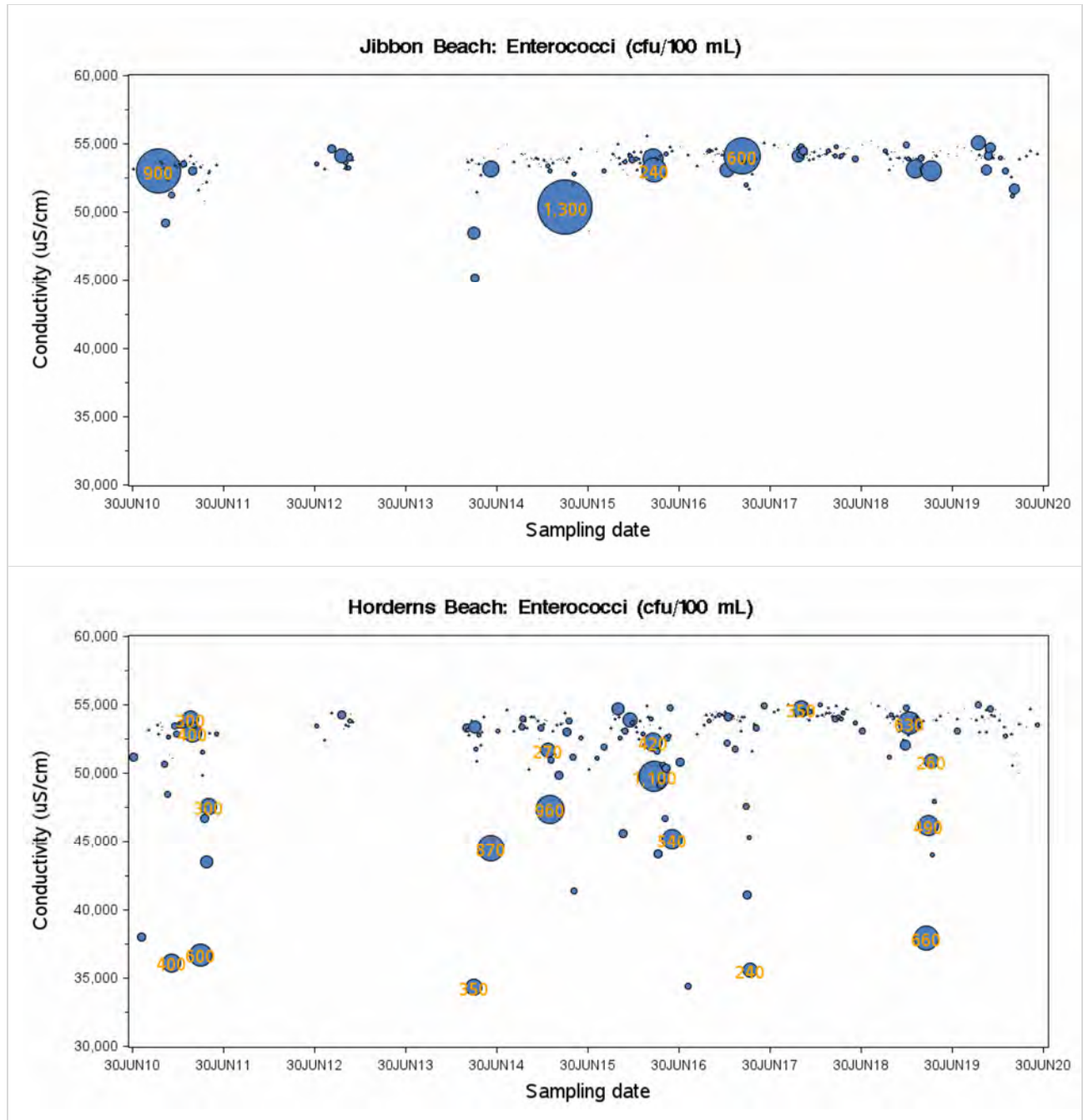


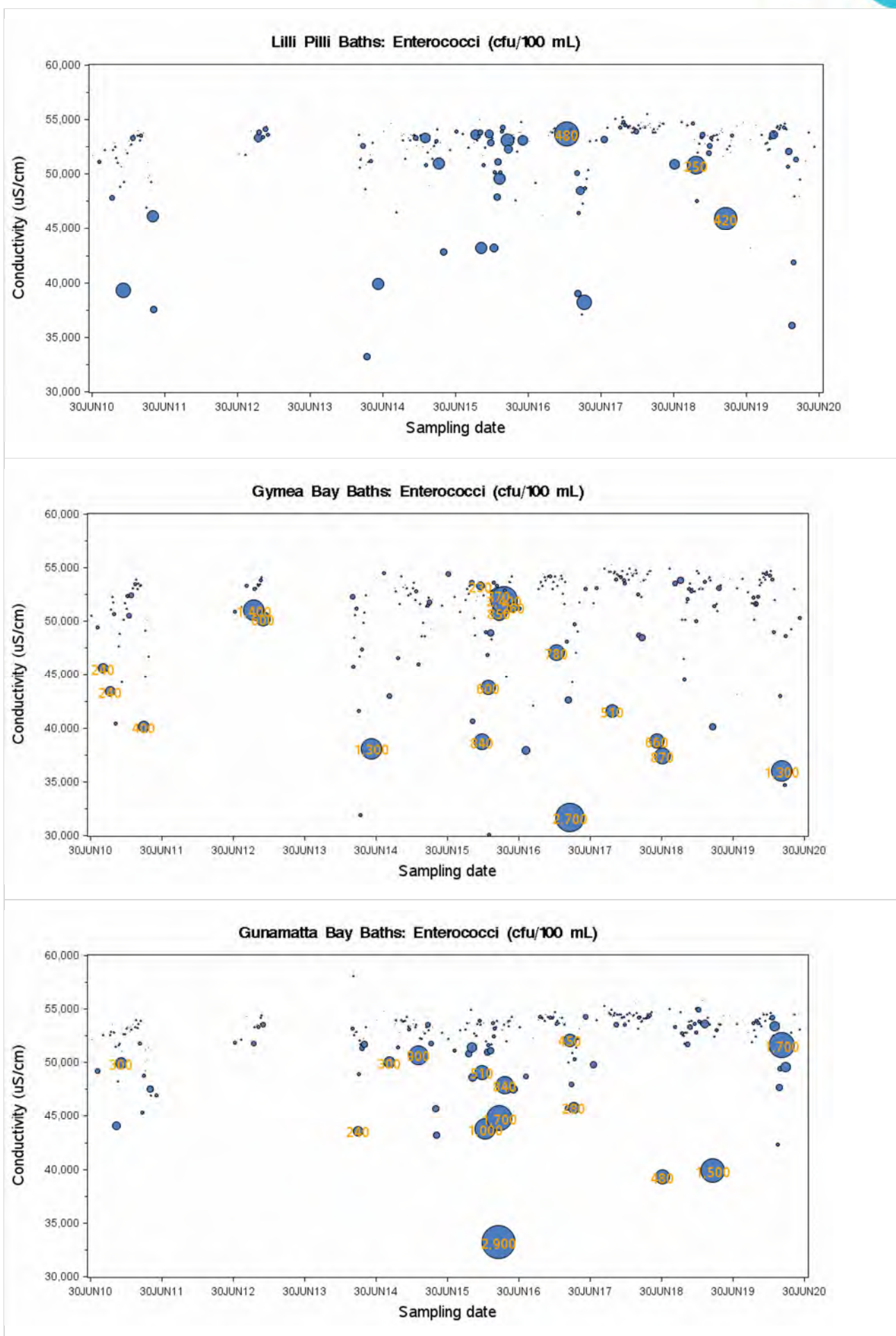




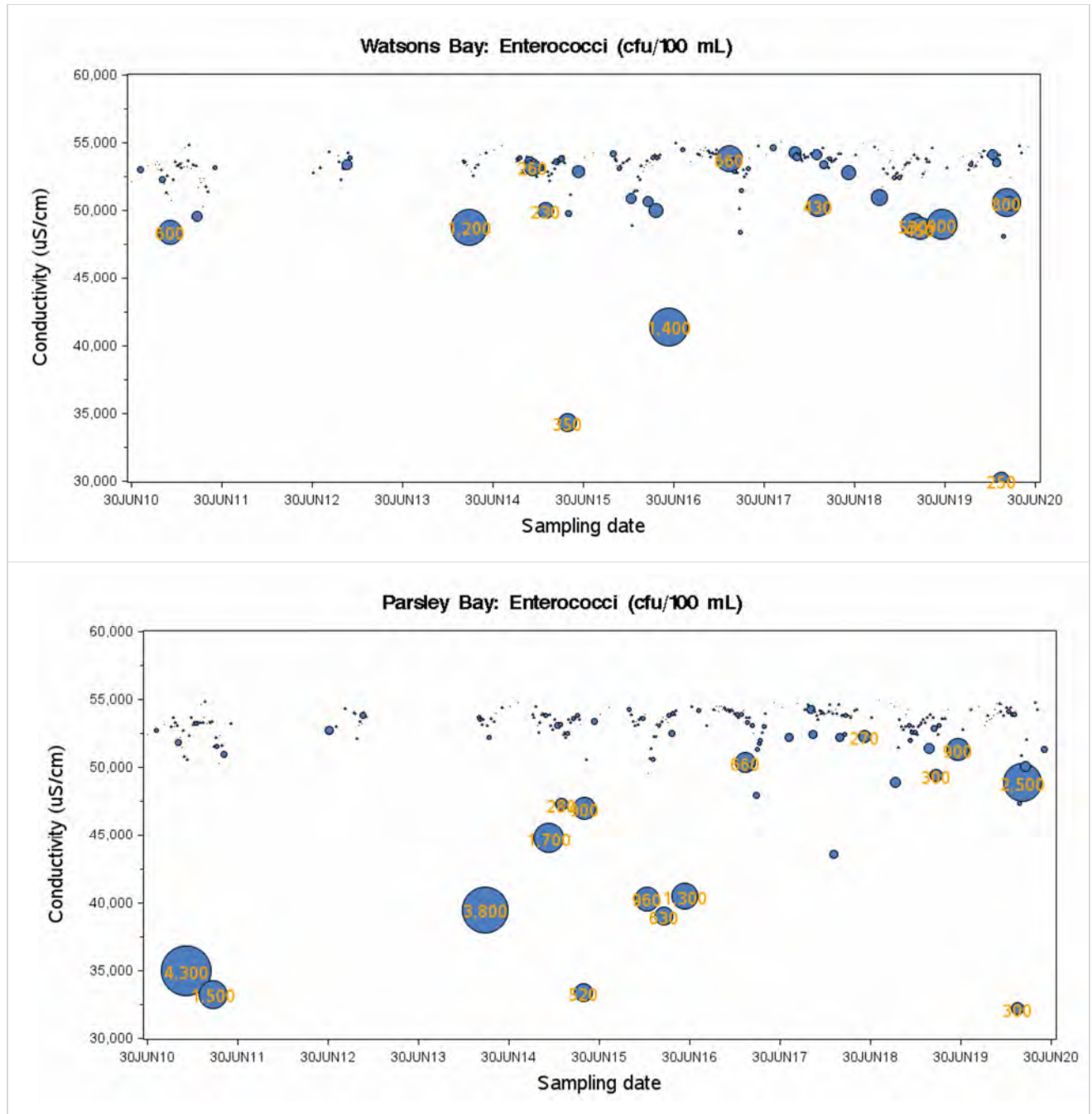


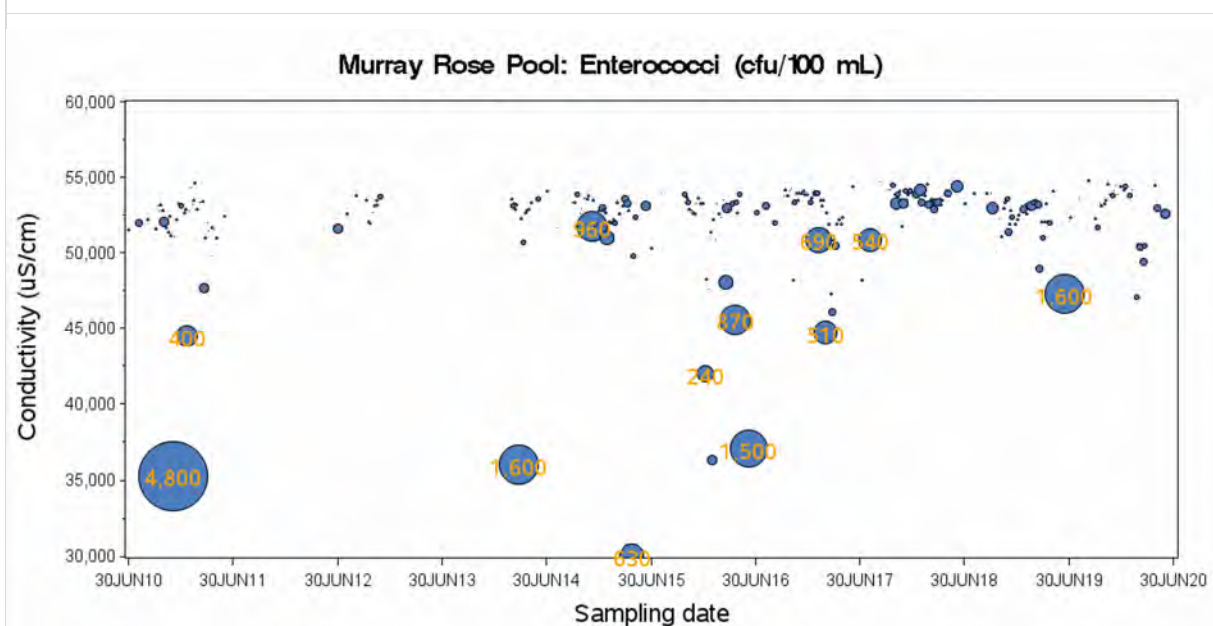
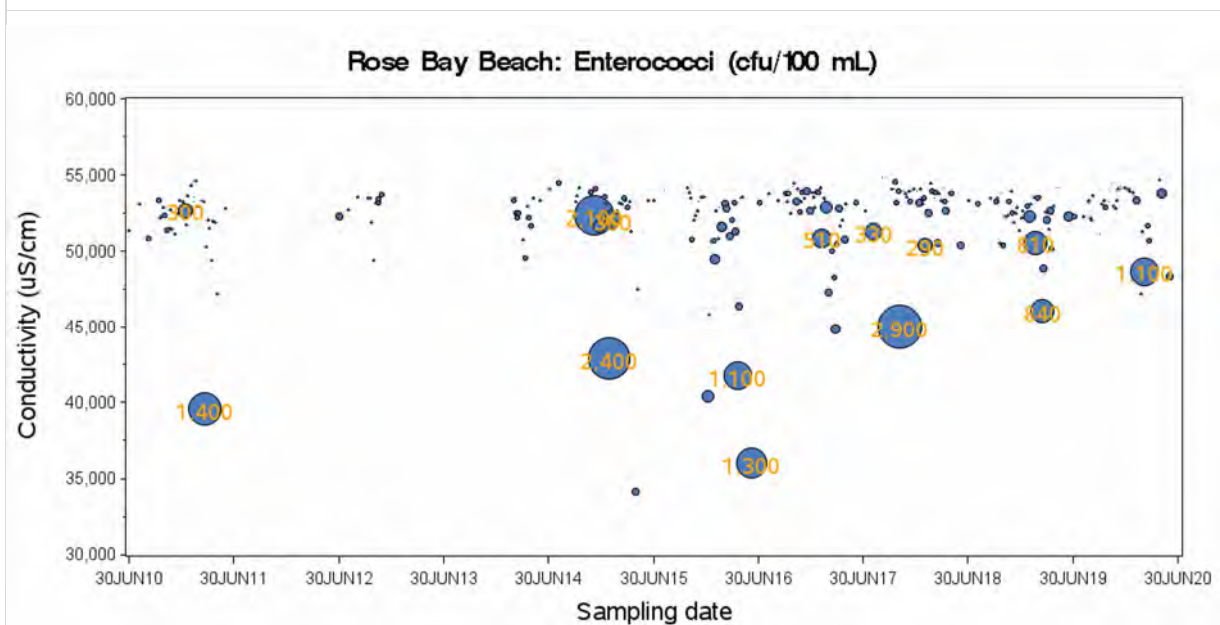
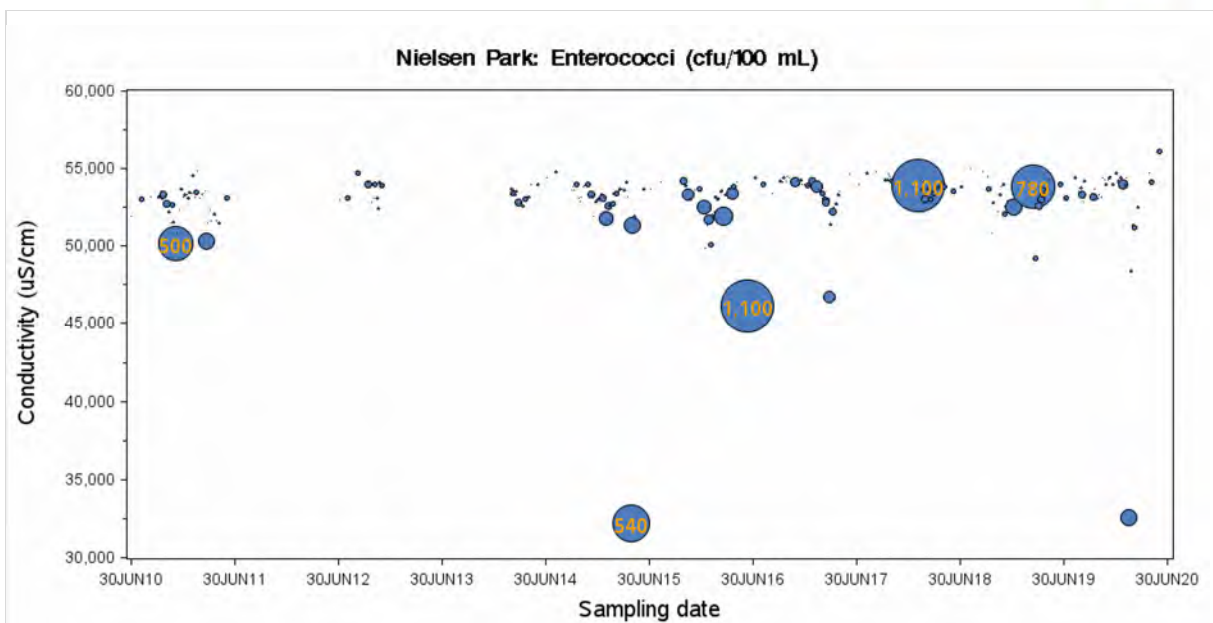
Sydney Harbour and Estuaries: Port Hacking

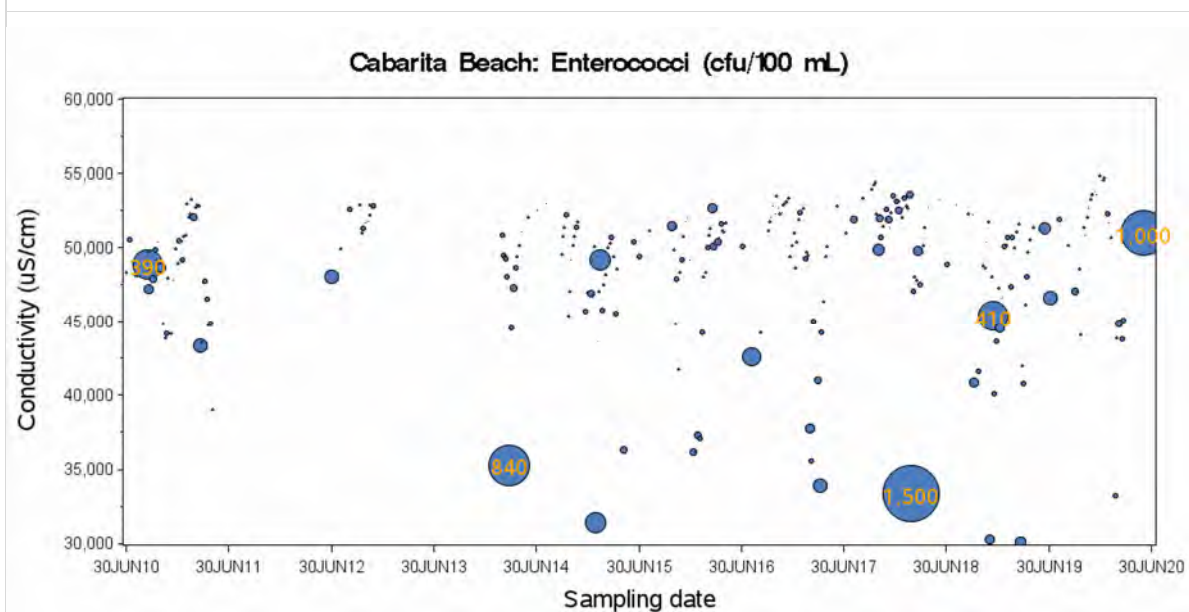
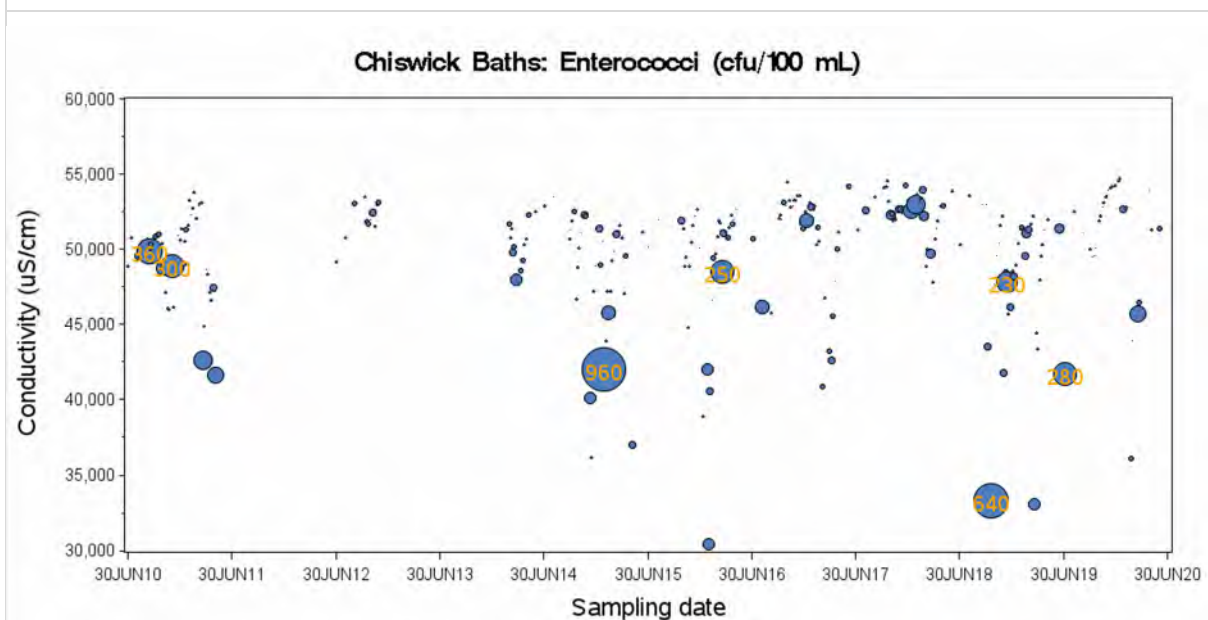
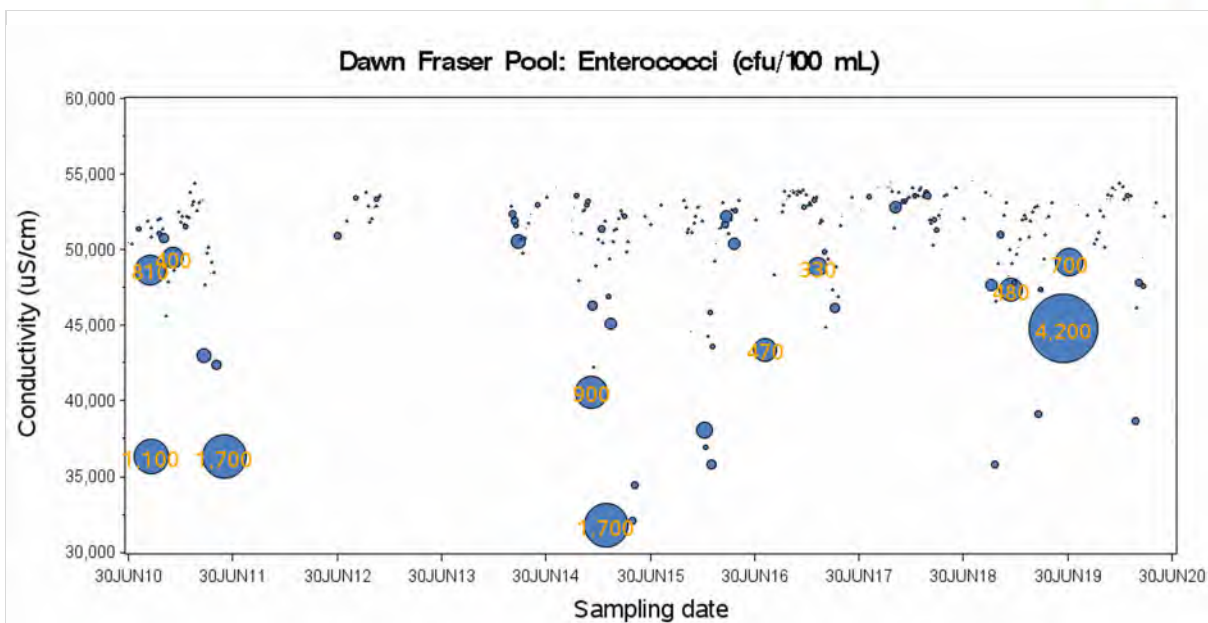


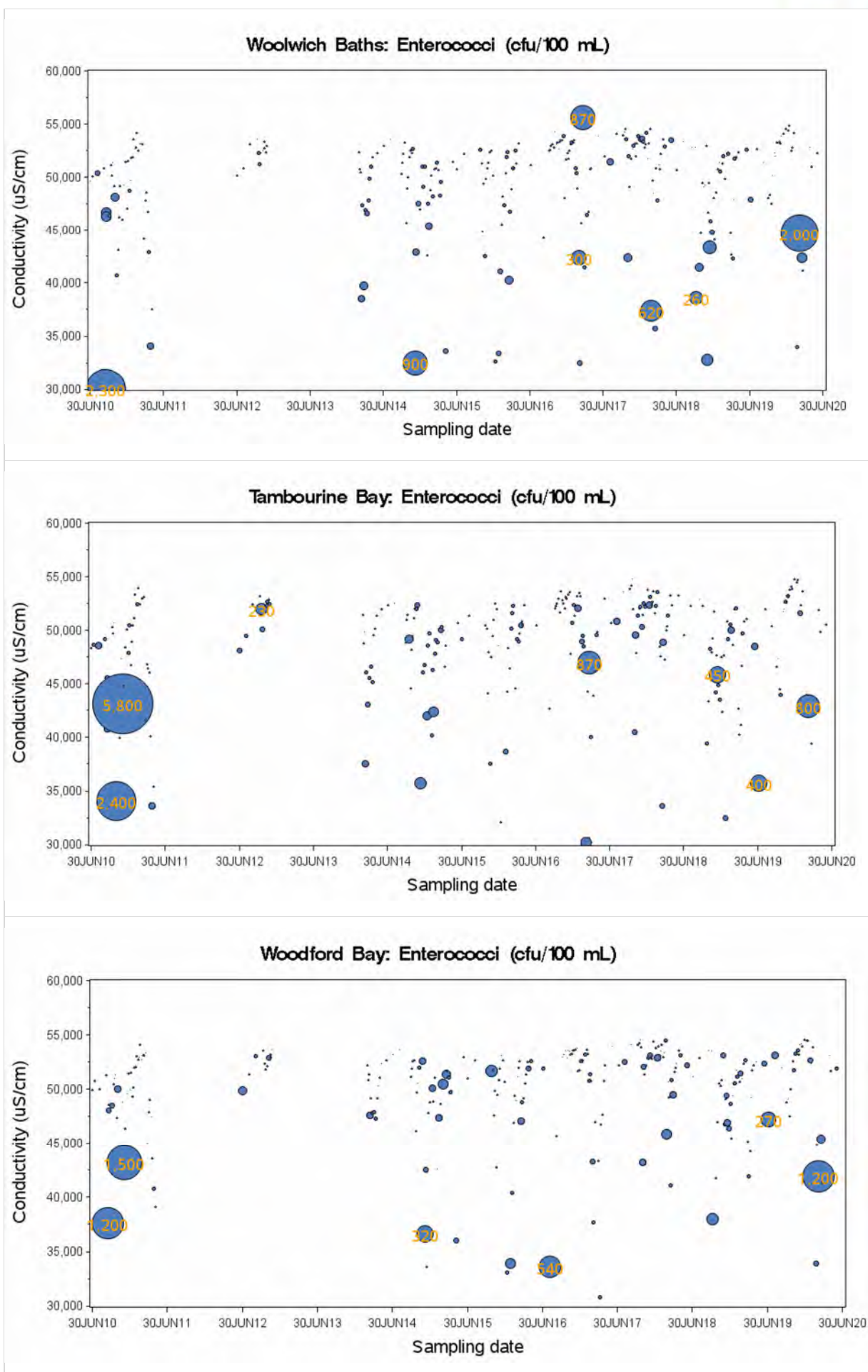


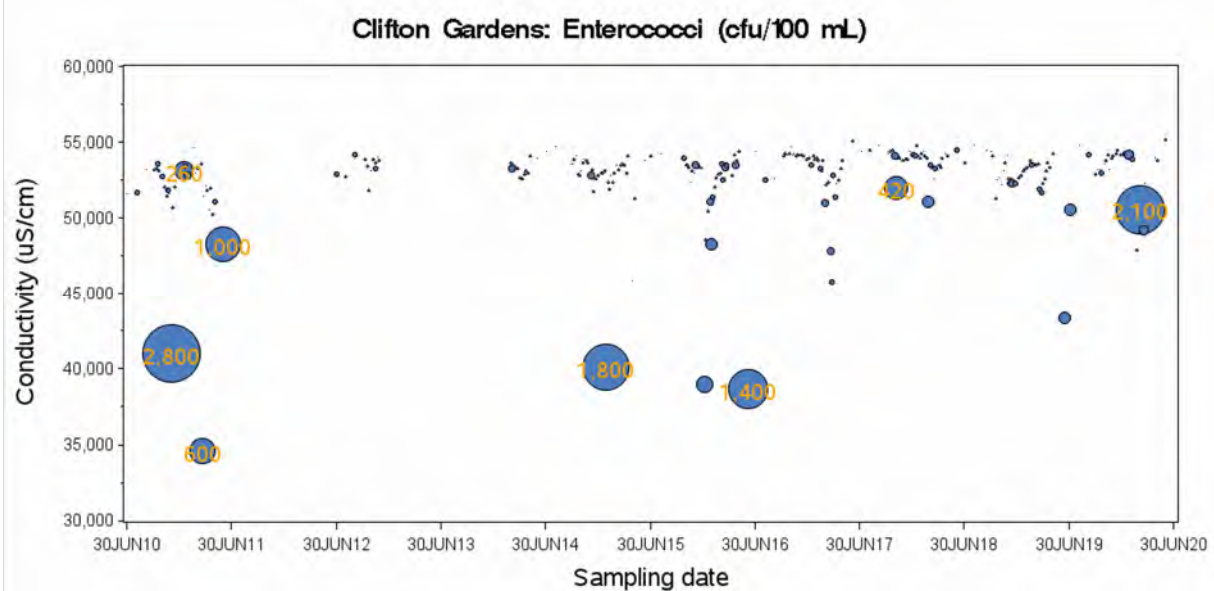
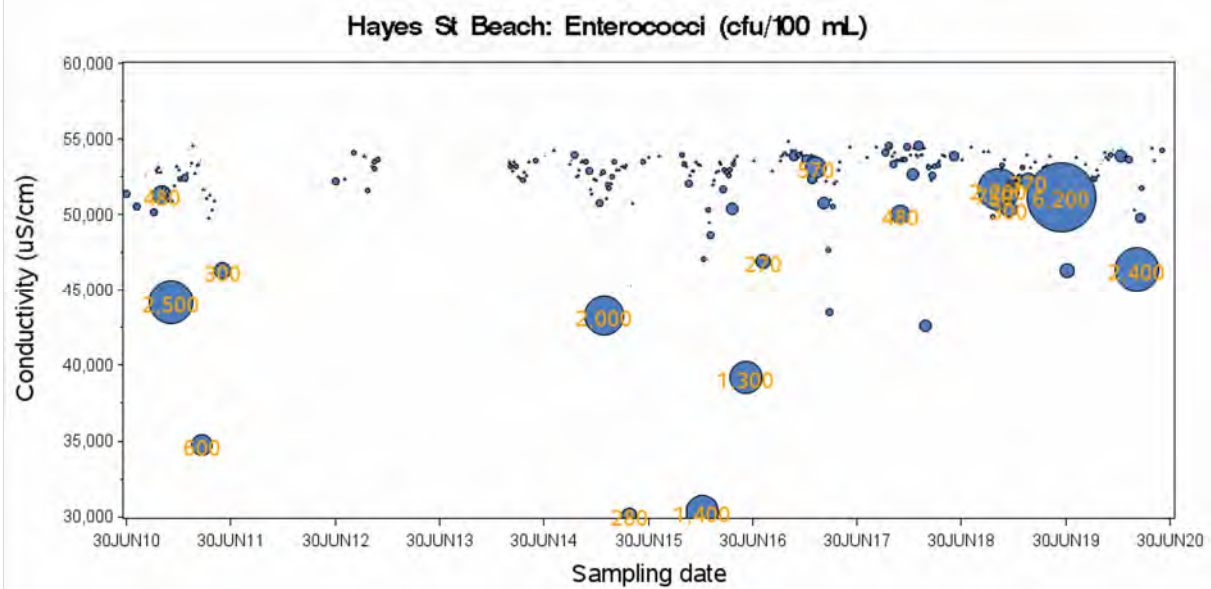
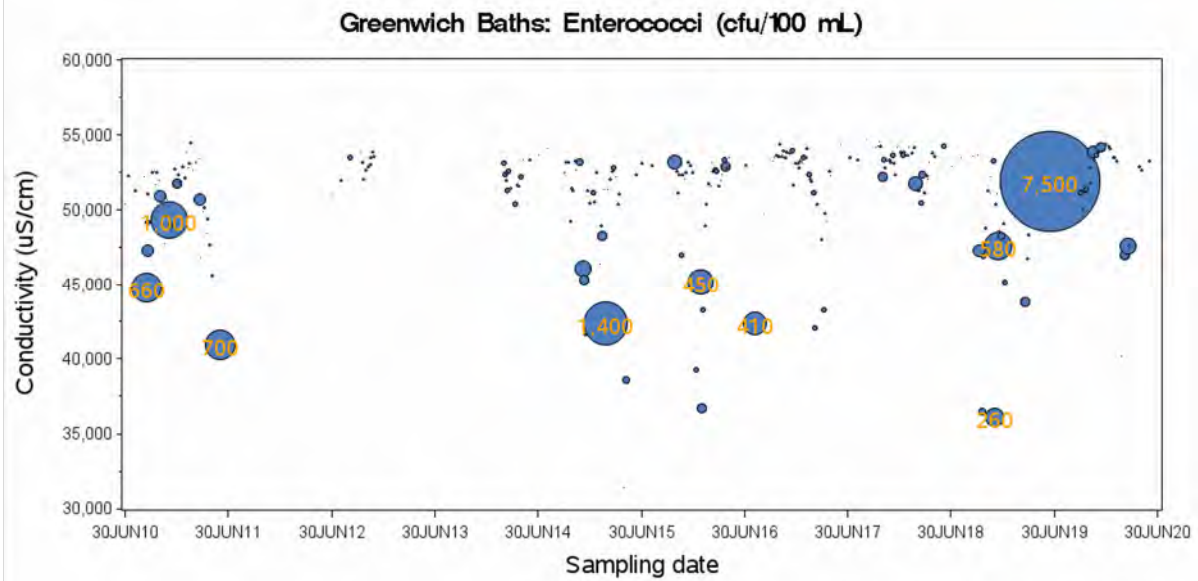
Sydney Harbour and Estuaries: Port Jackson



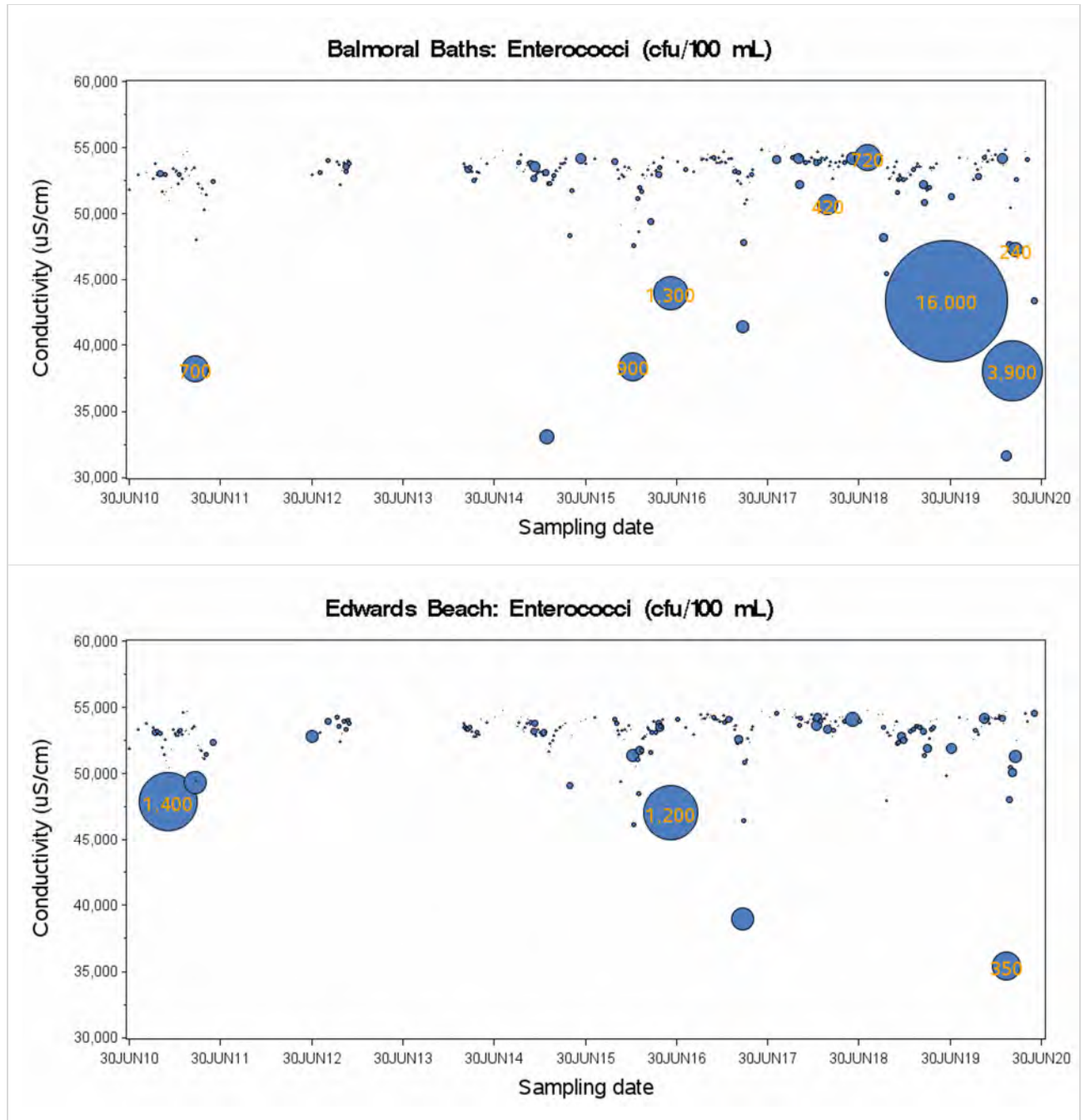


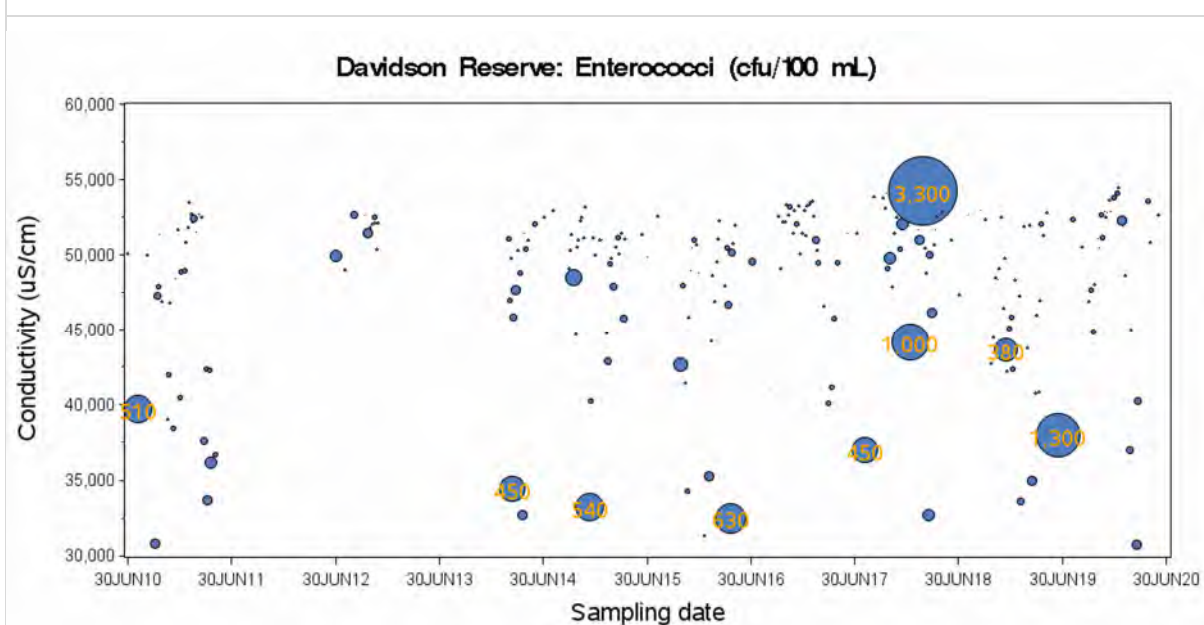
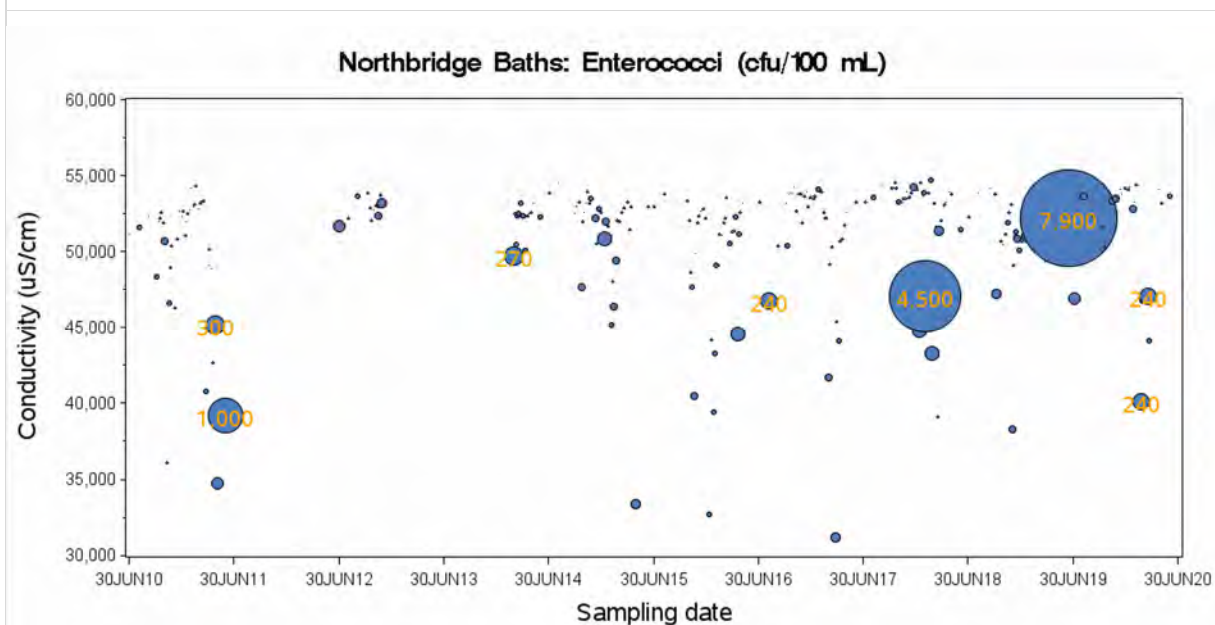
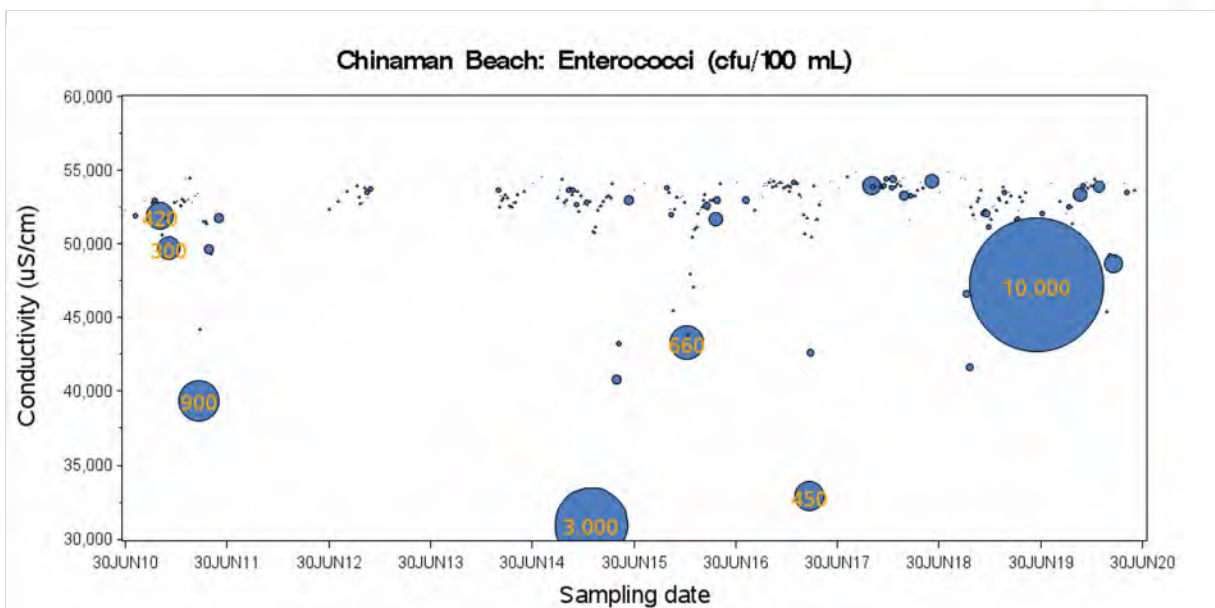


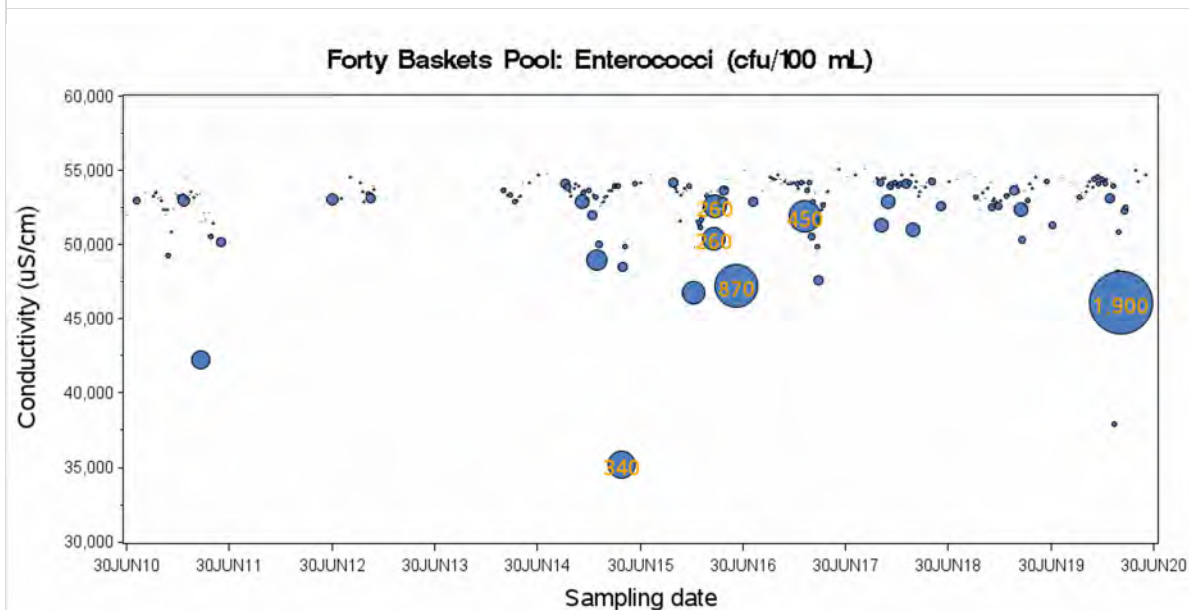
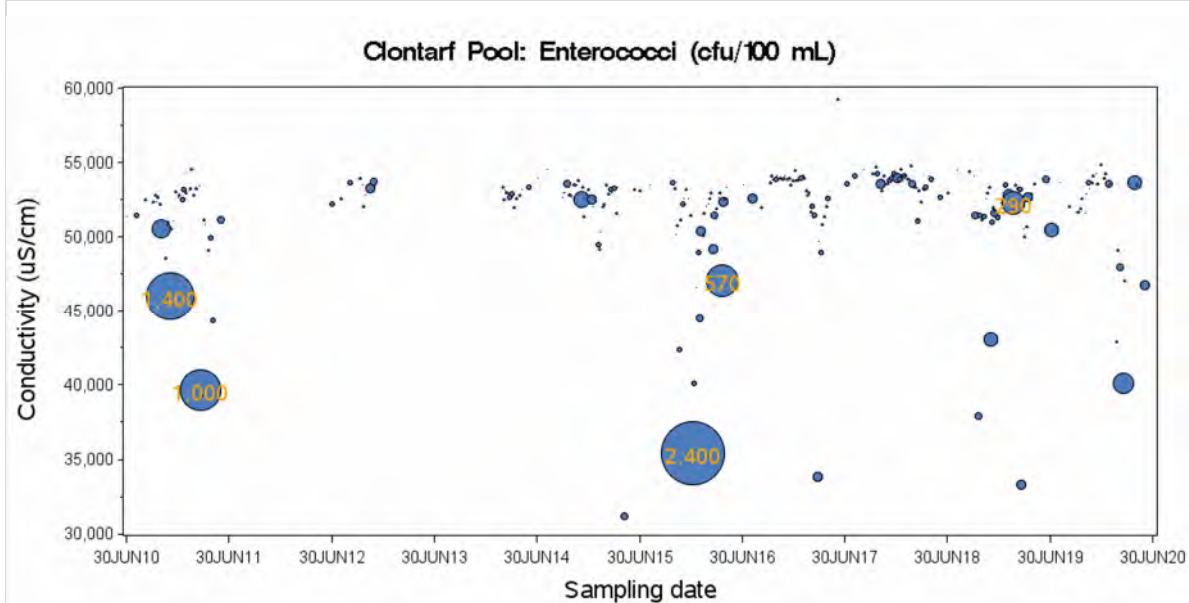
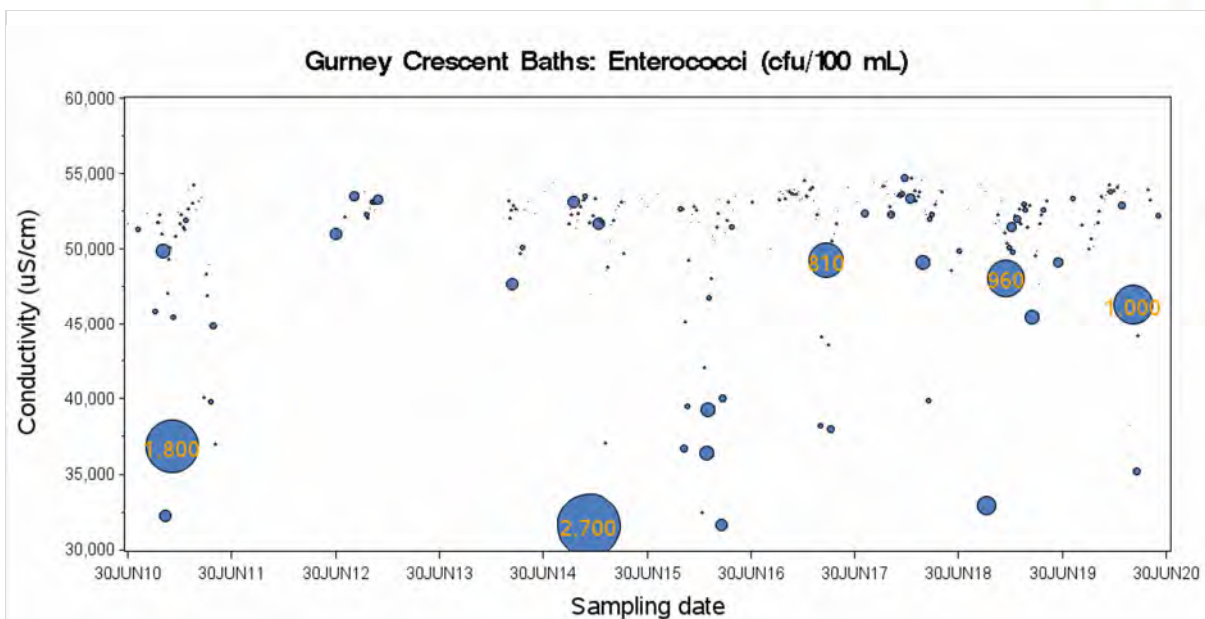


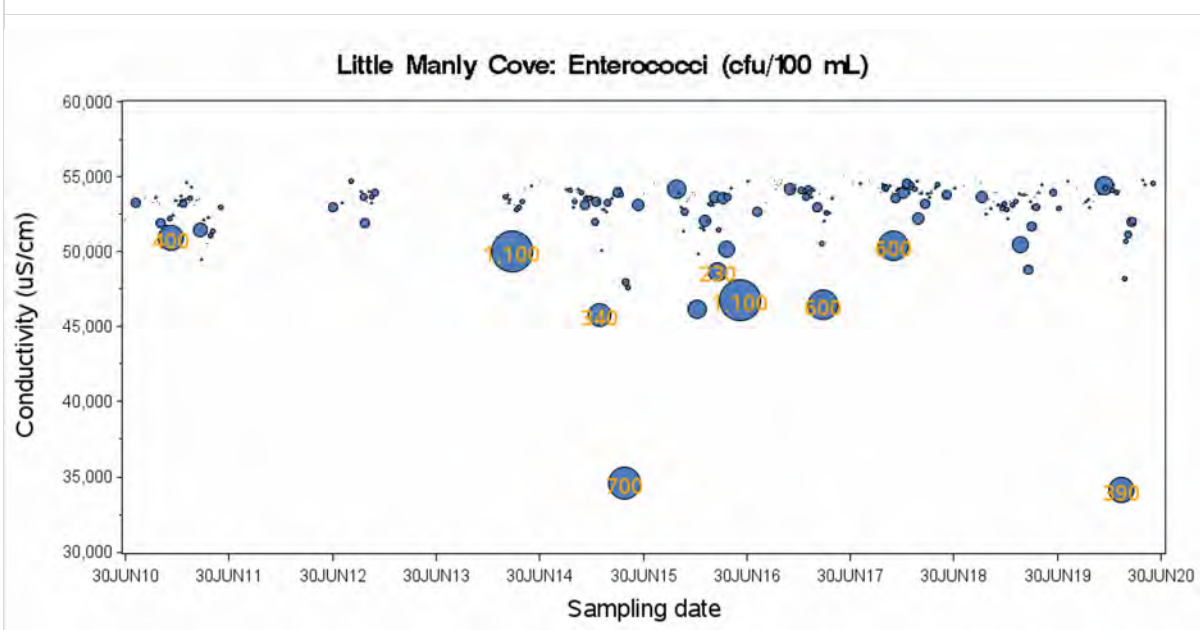
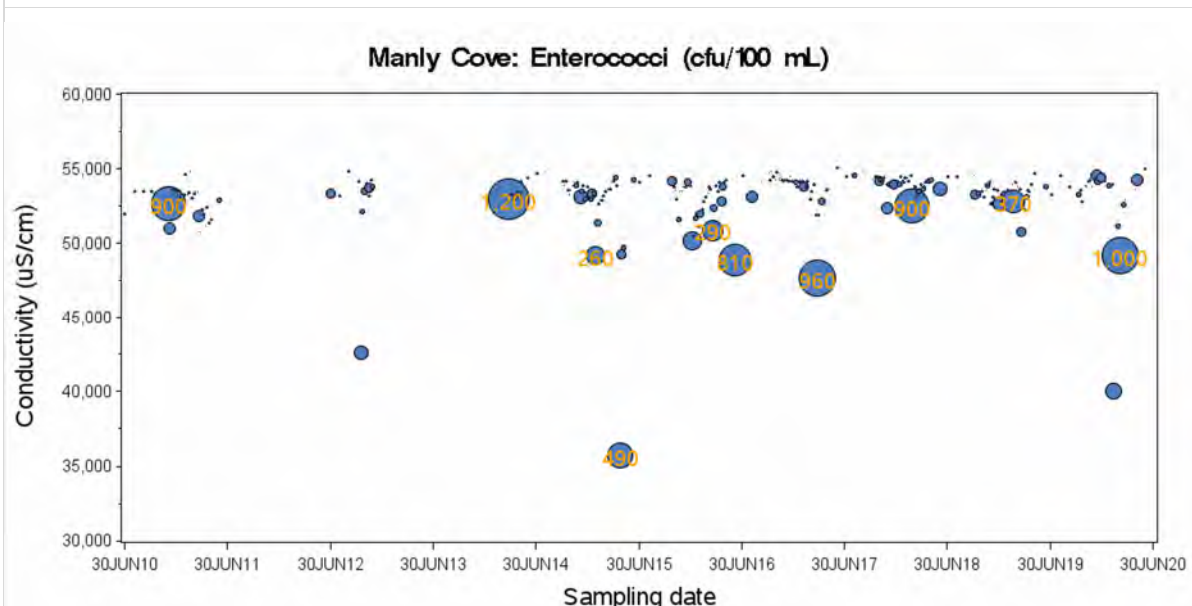
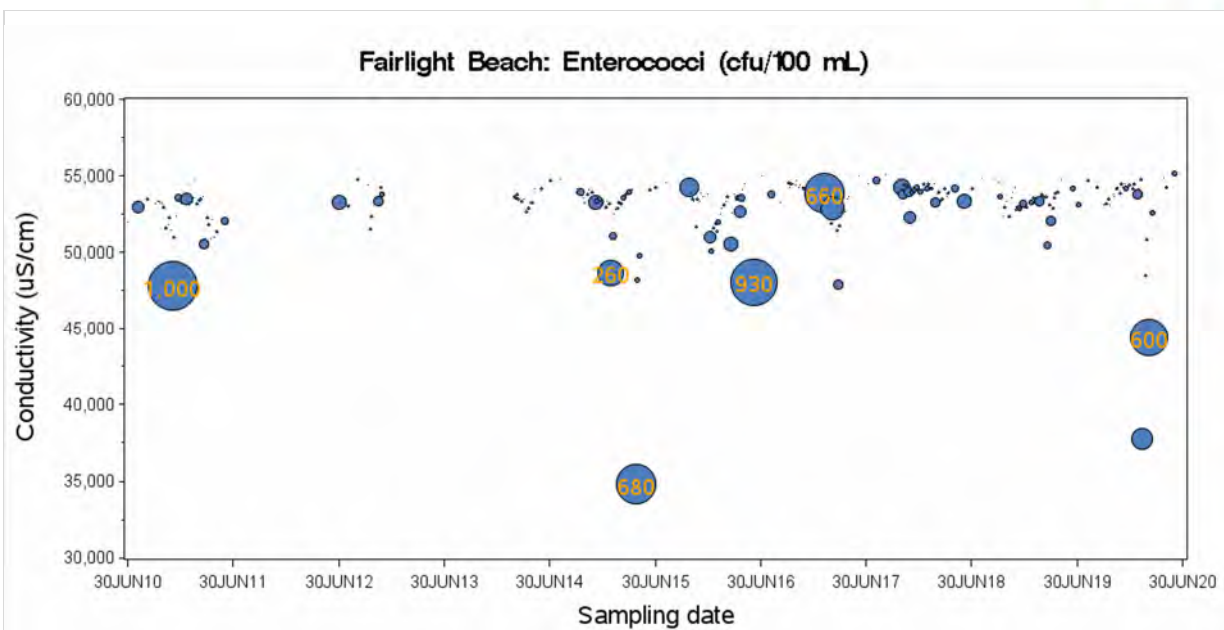


Sydney Harbour and Estuaries: Middle Harbour

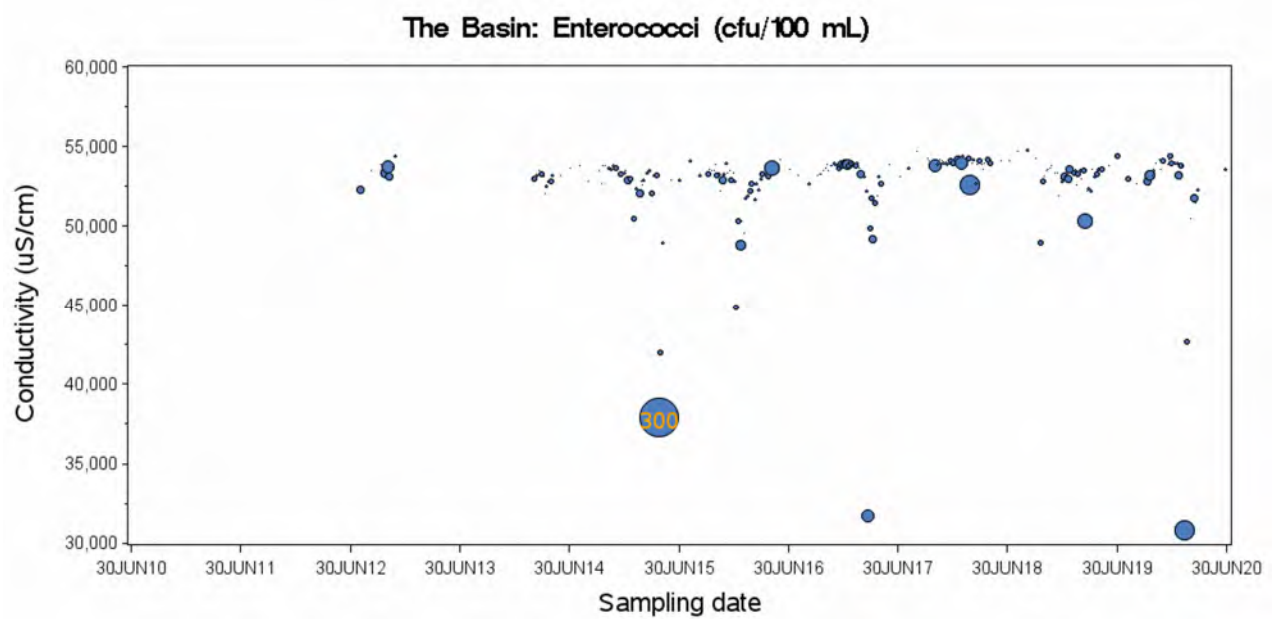
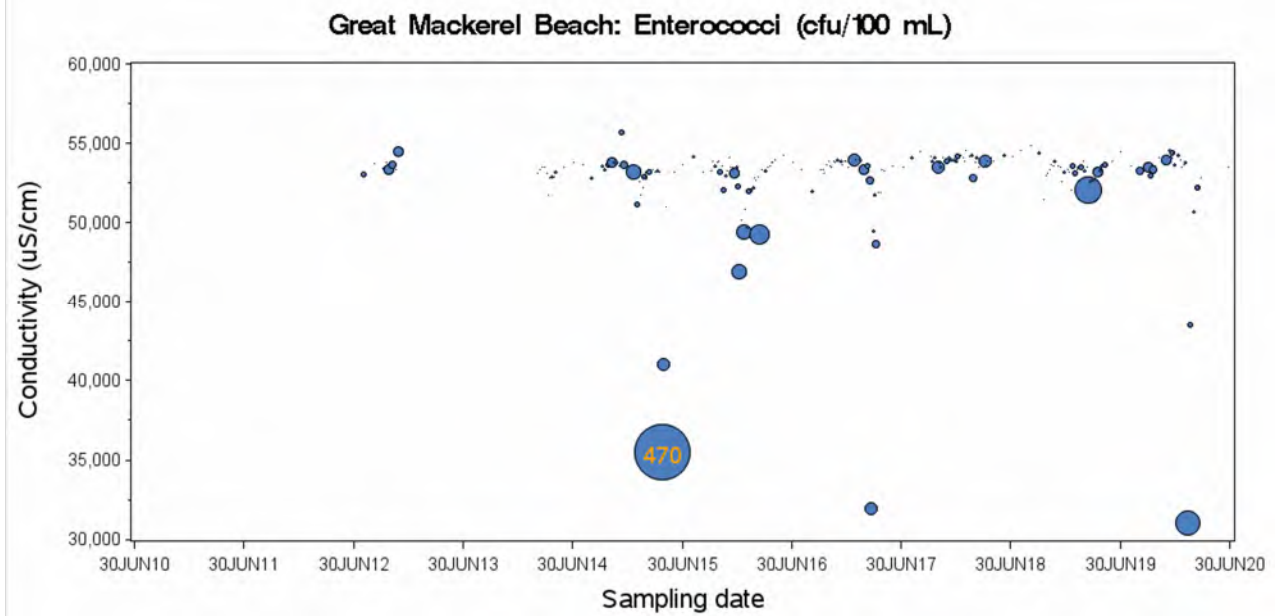


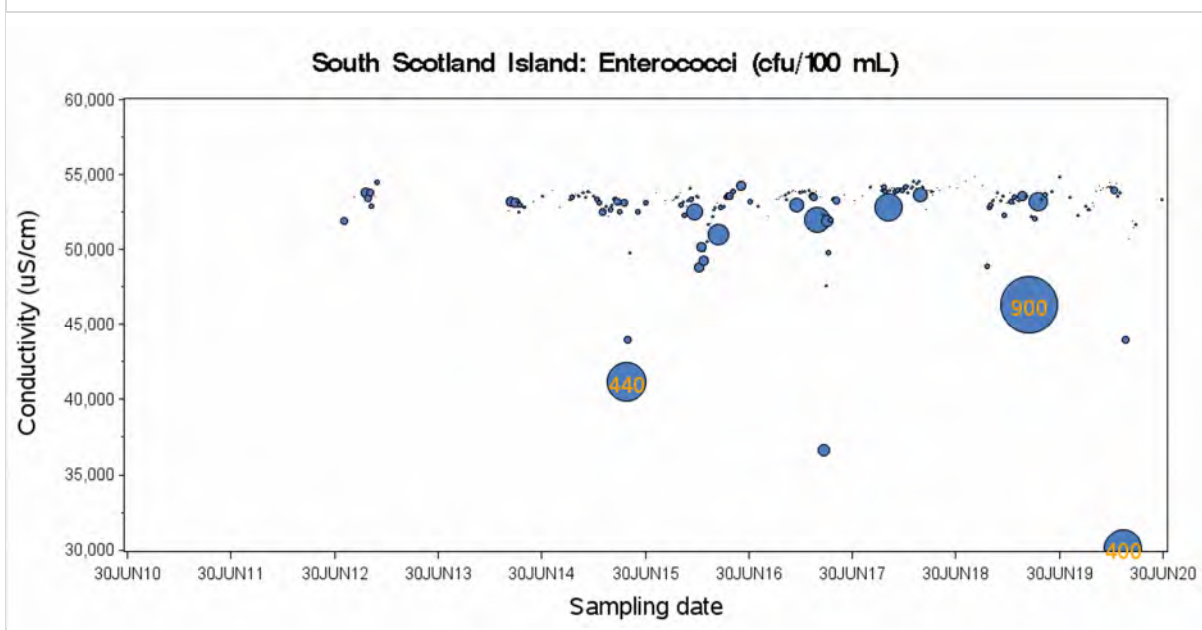
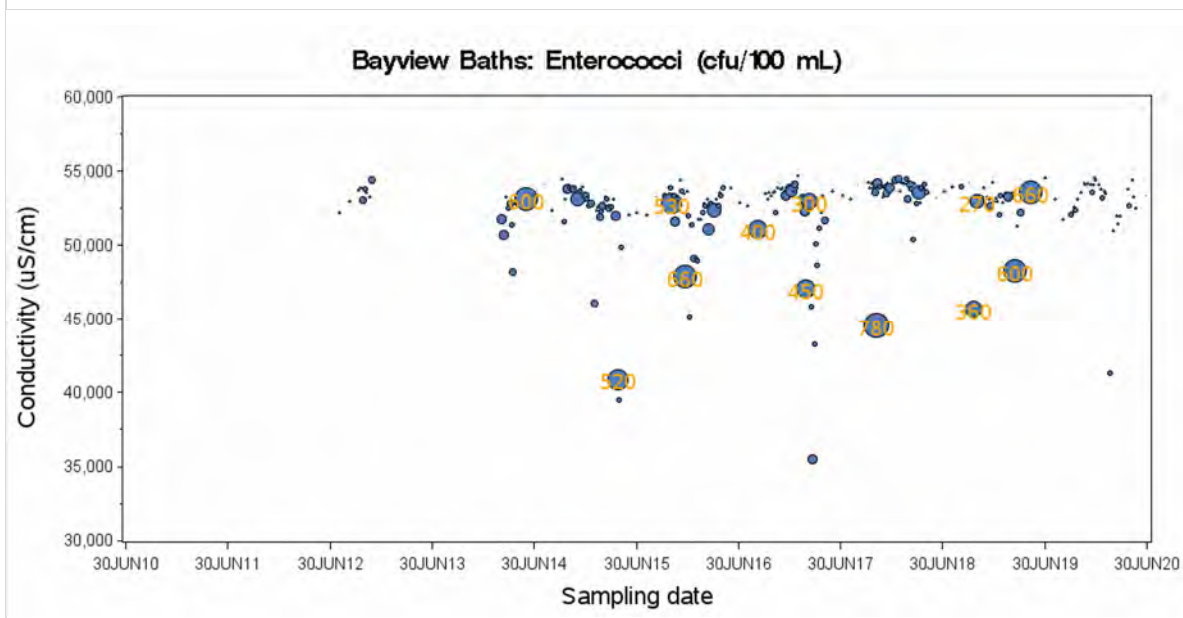
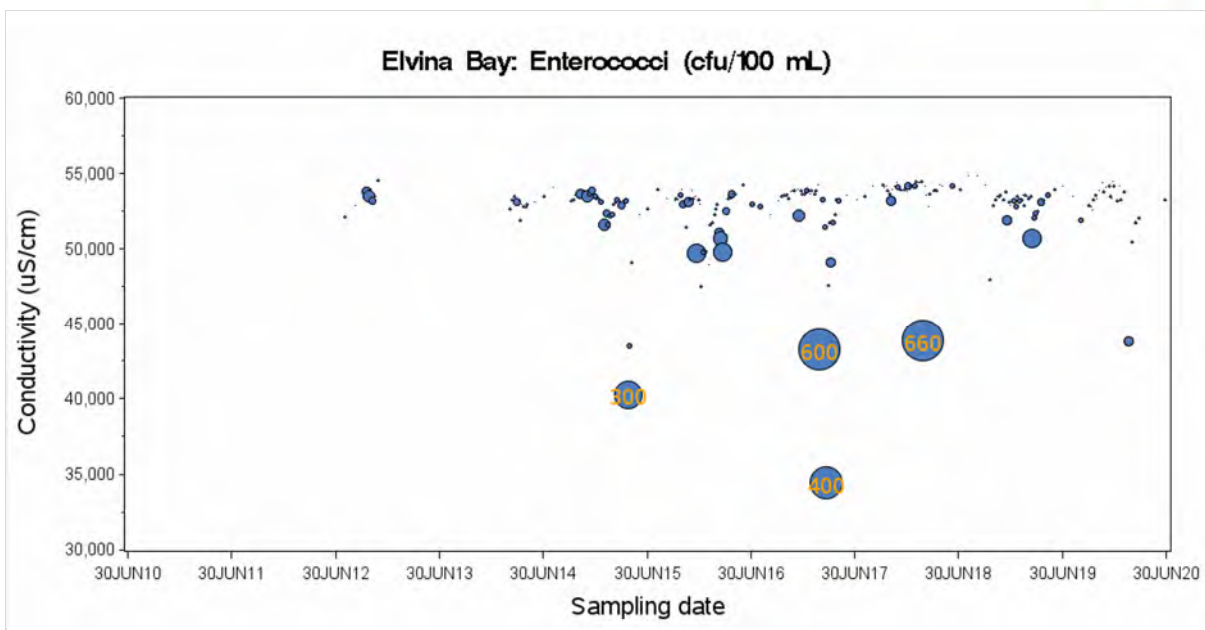


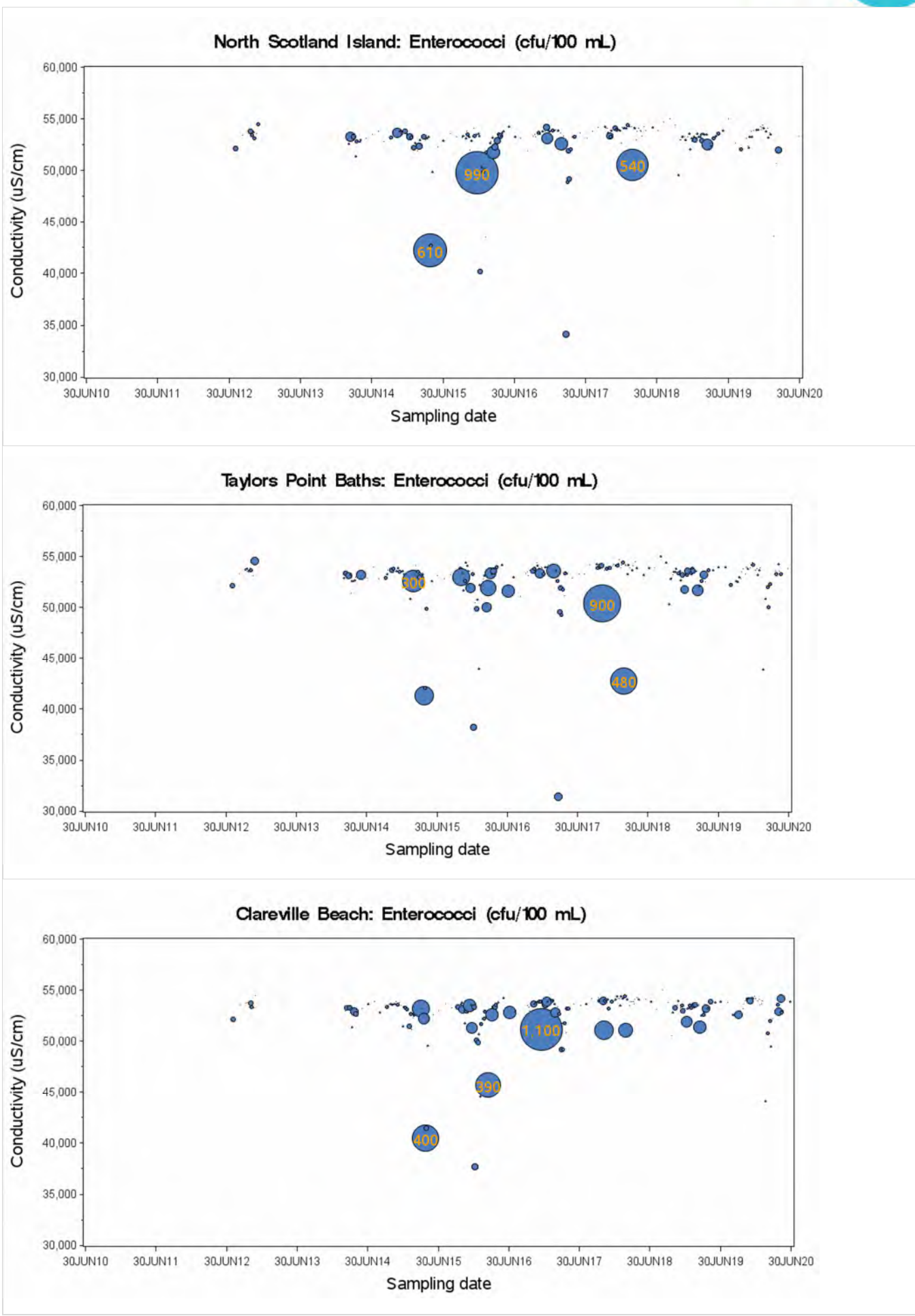




Sydney Harbour and Estuaries: Pittwater







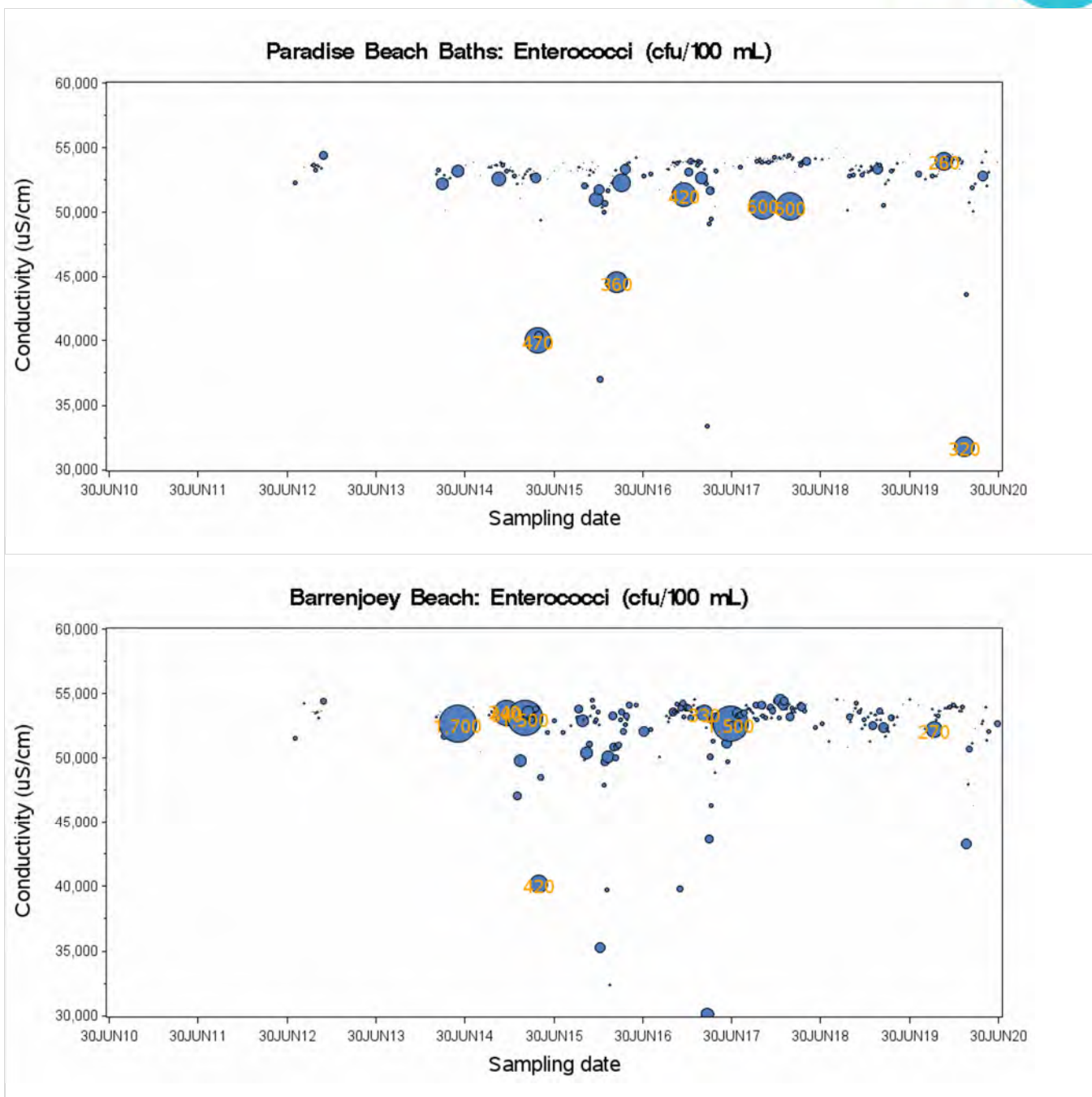


Table H-1. Short-listed dry weather *Enterococci* exceptions data (>35 cfu/100mL) based on catchment rainfall condition (2019-20)

Sampling site	Sampling date	<i>Enterococci</i> (cfu/100ML)	Conductivity (µS/cm)	72 hours rain ≤2 mm	Station no	Station name
Avalon Beach	18-Oct-19	130	53900	0	66079	Avalon Beach (Palmgrove Rd))
Balmoral Baths	24-Jan-20	130	54200	1.4	66006	Sydney Botanic Garden
Barrenjoey Beach	8-Oct-19	270	52200	0	66128	Palm Beach (Sunrise Road)
Bellambi Beach	20-Mar-20	260	53500	1.2	68228	Bellambi AWS
	1-Apr-20	2500	31800	0.8		
Bilarong Reserve	9-Aug-19	100	51100	0	66126	Collaroy (Long Reef Golf Club)
	16-Jan-20	1500	45500	0		
	29-Jan-20	62	42700	0		
	22-Apr-20	53	47800	0		
	25-May-20	150	50700	1.4		
Boat Harbour	4-Sep-19	130	52200	0	66058	Sans Souci (Public School)
	10-Oct-19	140	53900	2		
	13-Jan-20	35	54500	0		
	23-Mar-20	48	54000	1		
Bombo Beach	15-Dec-19	39	54200	0.2	68242	Kiama (Bombo Headland)
Bondi Beach	22-Oct-19	810	53900	0.9	66098	Rose Bay (Royal Sydney Golf Club)
Brighton Le Sands Baths	24-Feb-20	150	43800	1.6	66037	Sydney Airport AMO
Bronte Beach	12-Dec-19	46	54700	0	66098	Rose Bay (Royal Sydney Golf Club)
	24-Jan-20	38	54200	0		
Bulli Beach	1-Apr-20	570	50500	0.8	68108	Bellambi AWS
Camp Cove	12-Dec-19	89	54500	0	66098	Rose Bay (Royal Sydney Golf Club)
Chinamans Beach	19-Nov-19	110	53400	0	66006	Sydney Botanic Garden
	24-Jan-20	58	53900	1.4		
Clareville Beach	7-May-20	44	54200	0.6	66079	Avalon Beach (Palmgrove Rd))
Clifton Gardens	24-Jan-20	64	54200	1.4	66006	Sydney Botanic Garden
Clontarf Pool	27-Apr-20	94	53700	0	66080	Castle Cove (Rosebridge Ave)
Clovelly Beach	4-Sep-19	300	53700	0	66052	Randwick (Randwick St)
	23-Apr-20	37	55500	0	66052	Randwick (Randwick St)
Collaroy Beach	9-Aug-19	130	54300	0	66126	Collaroy (Long Reef Golf Club)
Como Baths	10-Oct-19	83	45600	2	66058	Sans Souci (Public School)
Congwong Bay	22-Oct-19	74	53700	0	66037	Sydney Airport AMO
	12-Dec-19	61	53800	0		
	24-Jan-20	140	54100	0		
Coogee Beach	4-Sep-19	70	53900	0	66098	Rose Bay (Royal Sydney Golf Club)
	12-Dec-19	170	54600	0		
	24-Jan-20	140	54000	0		
	4-May-20	66	54100	0		
Corrimal Beach	18-Jun-20	55	52900	0.4	68228	Bellambi AWS
Davidson Reserve	20-Mar-20	44	40300	0	66188	Belrose (Evelyn Place)

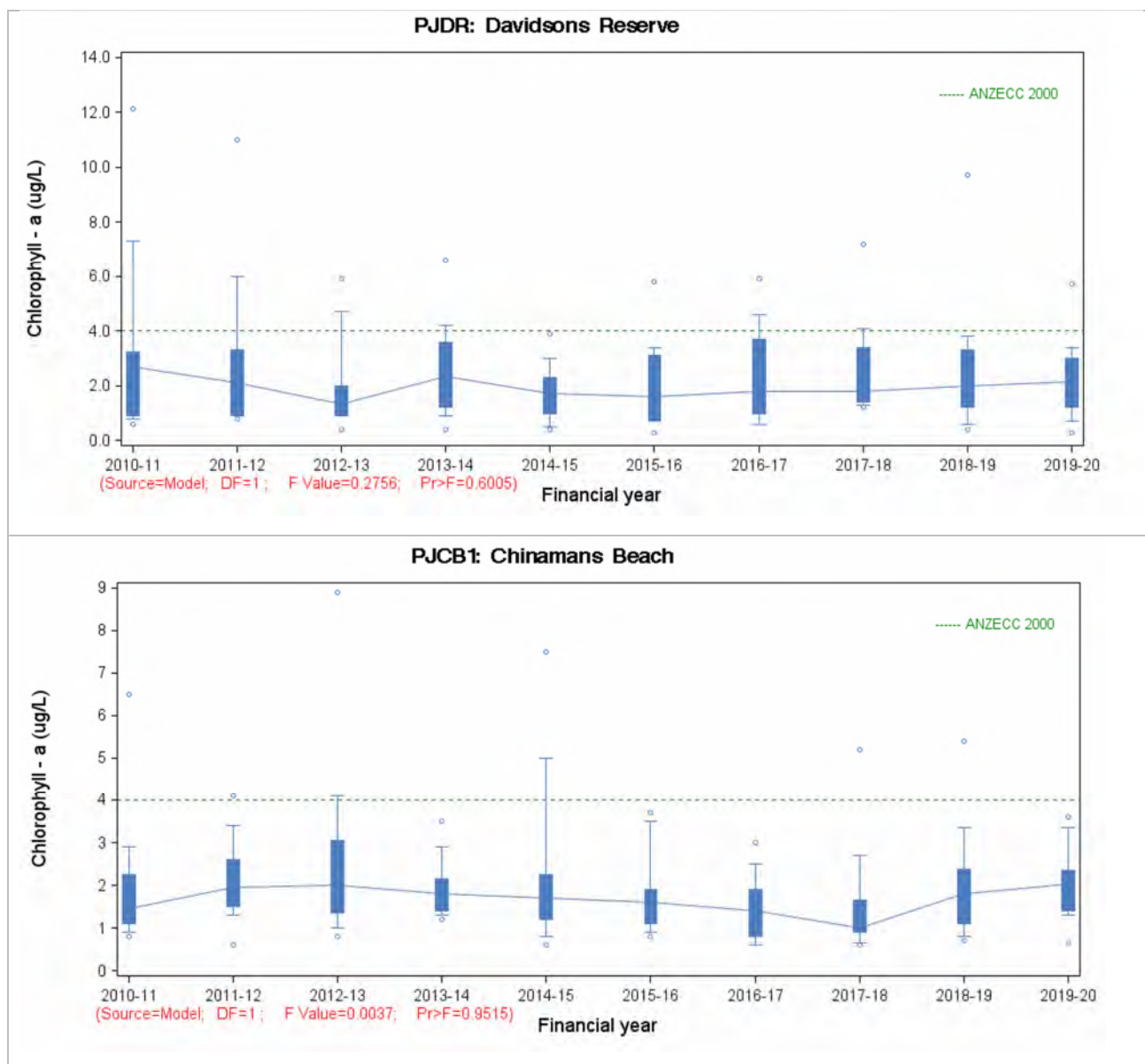
Sampling site	Sampling date	Enterococci (cfu/100ML)	Conductivity (µS/cm)	72 hours rain ≤2 mm	Station no	Station name
Dolls Point Baths	10-Dec-19	310	54100	0	66058	Sans Souci (Public School
	15-Jan-20	38	54100	0		
	21-Apr-20	190	45400	0		
Edwards Beach	13-Nov-19	43	54200	0	66006	Sydney Botanic Garden
Elouera Beach	10-Oct-19	110	54200	2	66058	Sans Souci (Public School
Fairlight Beach	24-Jan-20	42	53800	0	66080	Castle Cove (Rosebridge Ave)
Fisherman's Beach	15-Nov-19	35	54500	0	68131	Port Kembla (BSL Central Lab)
Forty Baskets Pool	24-Jan-20	42	53100	0	66080	Castle Cove (Rosebridge Ave)
Frenchmans Bay	14-Nov-19	58	54100	0	66037	Sydney Airport AMO
	10-Dec-19	590	54400	0		
	28-Jan-20	60	53300	0.2		
	24-Feb-20	78	46900	1.6		
Freshwater Beach	10-Jan-20	95	54200	0	66126	Collaroy (Long Reef Golf Club)
	16-Jan-20	100	54100	0		
Gordons Bay (East)	24-Jan-20	92	54200	0	66098	Rose Bay (Royal Sydney Golf Club)
Greenhills Beach	10-Oct-19	150	54600	2	66058	Sans Souci (Public School
	28-Feb-20	55	53500	0		
Greenwich Baths	13-Nov-19	96	53900	0	66034	Abbotsford (Blackwall Point Rd)
	12-Dec-19	63	54200	0		
Gunnamatta Bay Baths	15-Jan-20	47	54200	0	66058	Sans Souci (Public School
	28-Jan-20	200	53400	0		
	26-Feb-20	44	49400	0		
	24-Mar-20	210	49600	2		
Gymea Bay Baths	23-Oct-19	62	51600	0	66204	Oyster Bay (Green Point Road)
	26-Feb-20	44	43000	0		
Horderns Beach	17-Jul-19	36	53100	0	66204	Oyster Bay (Green Point Road)
	10-Oct-19	50	55000	0.4		
Jew Fish Bay Baths	14-Nov-19	38	48500	0	66058	Sans Souci (Public School
Jibbon Beach	10-Oct-19	92	55100	0	66176	Audley (Royal National Park)
	14-Nov-19	38	53100	0		
Kiama Beach	15-Dec-19	77	54300	0.2	68252	Kiama (Brighton St)
Kyeemagh Baths	28-Jan-20	98	52600	0.2	66037	Sydney Airport AMO
	24-Feb-20	200	43200	1.6		
Lake Illawarra Entrance Lagoon Beach	15-Dec-19	150	54800	0.1	68246	Blackbutt (Tammar Place)
	14-Jan-20	660	55100	0.2		
	7-Apr-20	100	53300	0		
	19-Apr-20	46	53700	0		
	25-May-20	68	54500	1		
Lilli Pilli Baths	11-Nov-19	61	53600	0	66204	Oyster Bay (Green Point Road)

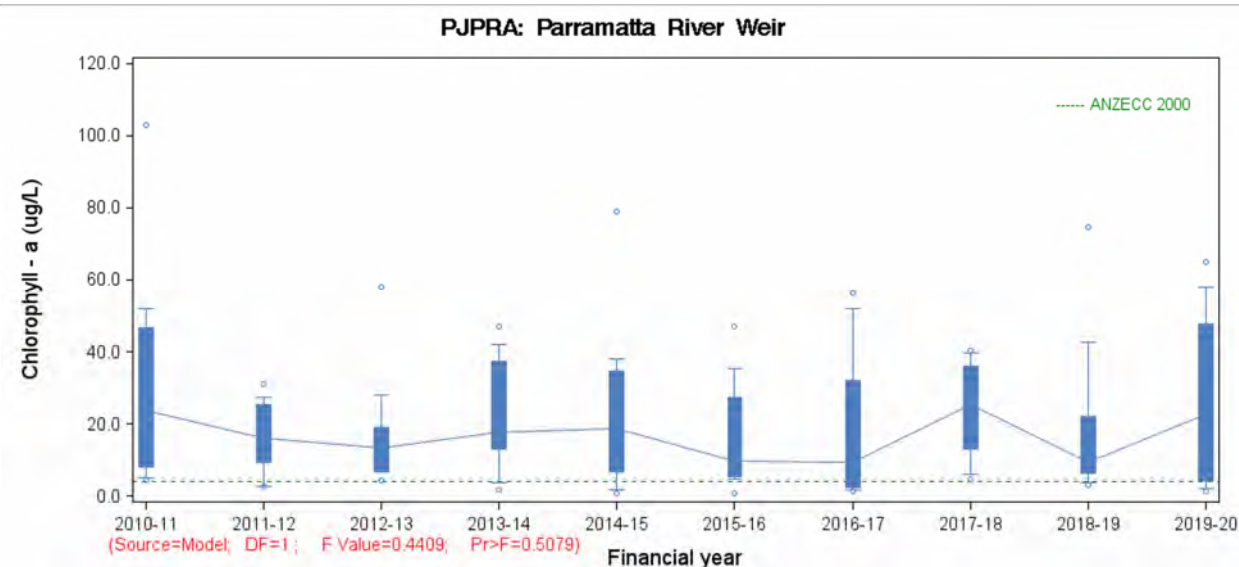
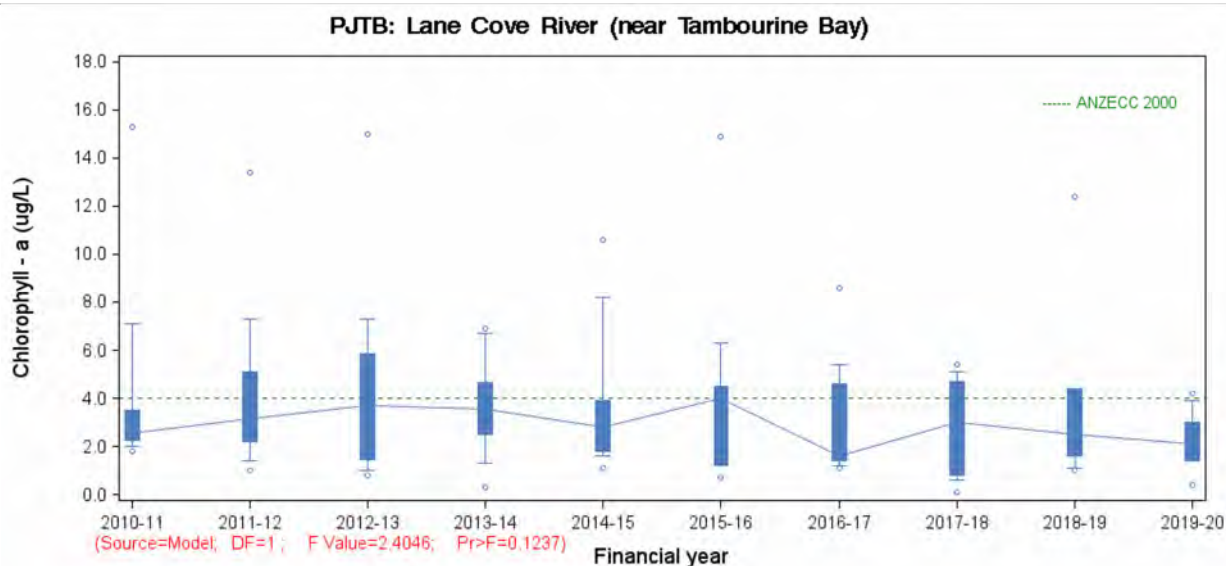
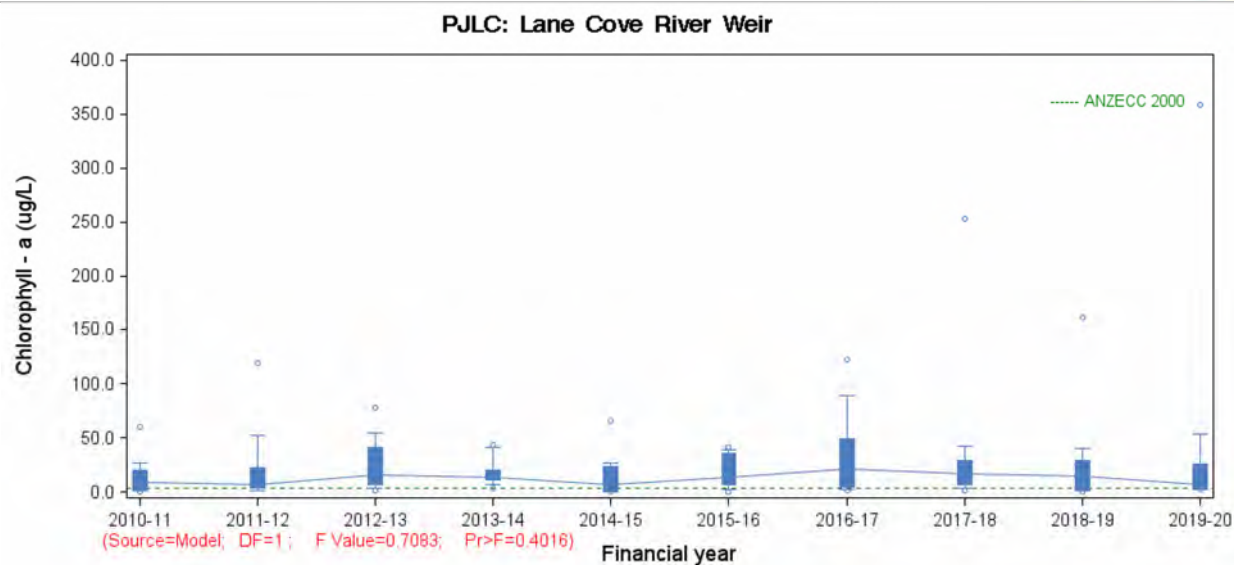
Sampling site	Sampling date	Enterococci (cfu/100ML)	Conductivity (µS/cm)	72 hours rain ≤2 mm	Station no	Station name
Little Bay Beach	13-Nov-19	38	54700	0	66052	Randwick (Randwick St)
	12-Dec-19	50	53600	0		
	24-Jan-20	390	54200	0.1		
Little Manly Cove	12-Dec-19	200	54400	0	66126	Collaroy (Long Reef Golf Club)
Long Reef Beach	6-Sep-19	83	54000	0		Collaroy (Long Reef Golf Club)
Malabar Beach	13-Aug-19	150	54800	0.6	66052	Randwick (Randwick St)
	13-Nov-19	55	54500	0		
	12-Dec-19	94	54200	0		
	24-Jan-20	250	54200	0.1		
	23-Apr-20	38	55500	0		
	4-May-20	81	54800	0		
	25-Jun-20	35	54700	1		
Manly Cove	12-Dec-19	82	54600	0	66126	Collaroy (Long Reef Golf Club)
	18-Dec-19	40	54200	0		
	30-Dec-19	63	54400	0		
	4-May-20	80	54300	0		
Maroubra Beach	24-Jan-20	330	54600	0.1	66053	Randwick (Randwick St)
	23-Apr-20	260	54900	0		
	4-May-20	58	54600	0		
Mona Vale Beach	9-Aug-19	120	54100	0	66079	Avalon Beach (Palmgrove Rd))
	18-Oct-19	35	54800	0.4	66141	Mona Vale Golf Club
Monterey Baths	28-Jan-20	66	53100	0	66058	Sans Souci (Public School
Murray Rose Pool	4-May-20	40	53000	0	66098	Rose Bay (Royal Sydney Golf Club)
Narrabeen Lagoon (Birdwood Park)	9-Aug-19	80	51000	0.4	66141	Mona Vale Golf Club
	18-Nov-19	79	43400	0	66141	
	30-Dec-19	35	45800	0		
	22-Apr-20	120	51900	0.2		
	5-Jun-20	35	52100	0.2		
	18-Jun-20	36	49800	0.2		
Newport Beach	9-Aug-19	39	53700	0	66079	Avalon Beach (Palmgrove Rd))
Nielsen Park	24-Jan-20	37	54000	0	66098	Rose Bay (Royal Sydney Golf Club)
North Curl Curl Beach	9-Aug-19	60	54800	0	66126	Collaroy (Long Reef Golf Club)
North Narrabeen Beach	9-Aug-19	180	54200	0.4	66141	Mona Vale Golf Club
	6-Sep-19	36	50100	0.6		
	16-Jan-20	100	54100	0.2		
North Wollongong Beach	14-Jan-20	780	54200	0	68228	Bellambi AWS
Northbridge Baths	24-Jan-20	46	52800	0	66080	Castle Cove (Rosebridge Ave)
Paradise Beach Baths	18-Nov-19	260	54000	0	66128	Palm Beach (Sunrise Road)
	27-Nov-19	46	54400	0.8	68131	Port Kembla (BSL Central Lab)

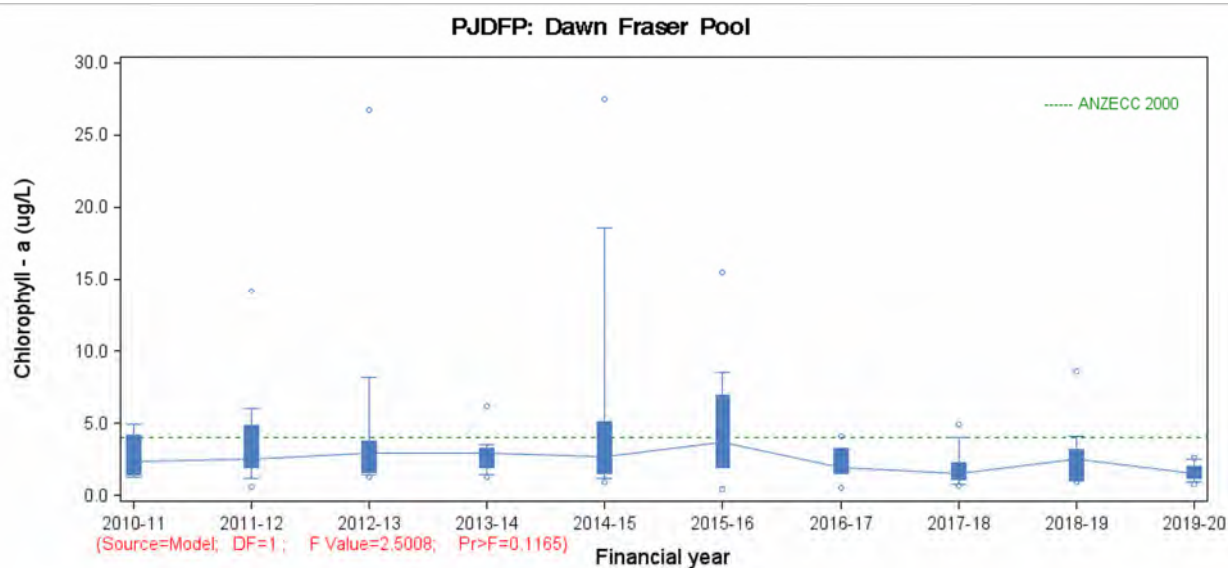
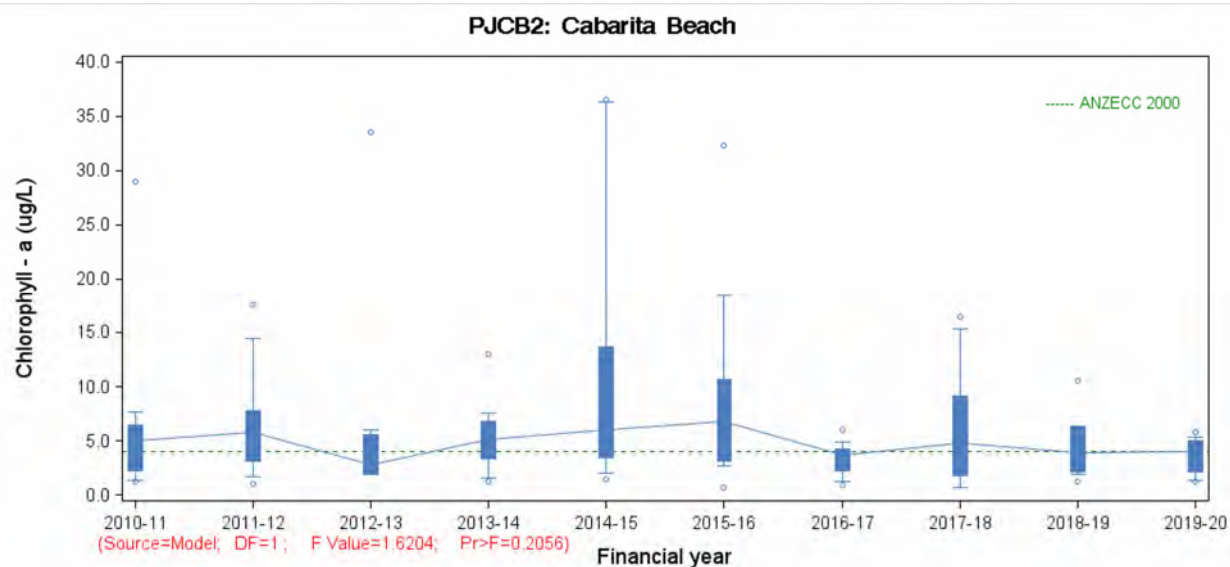
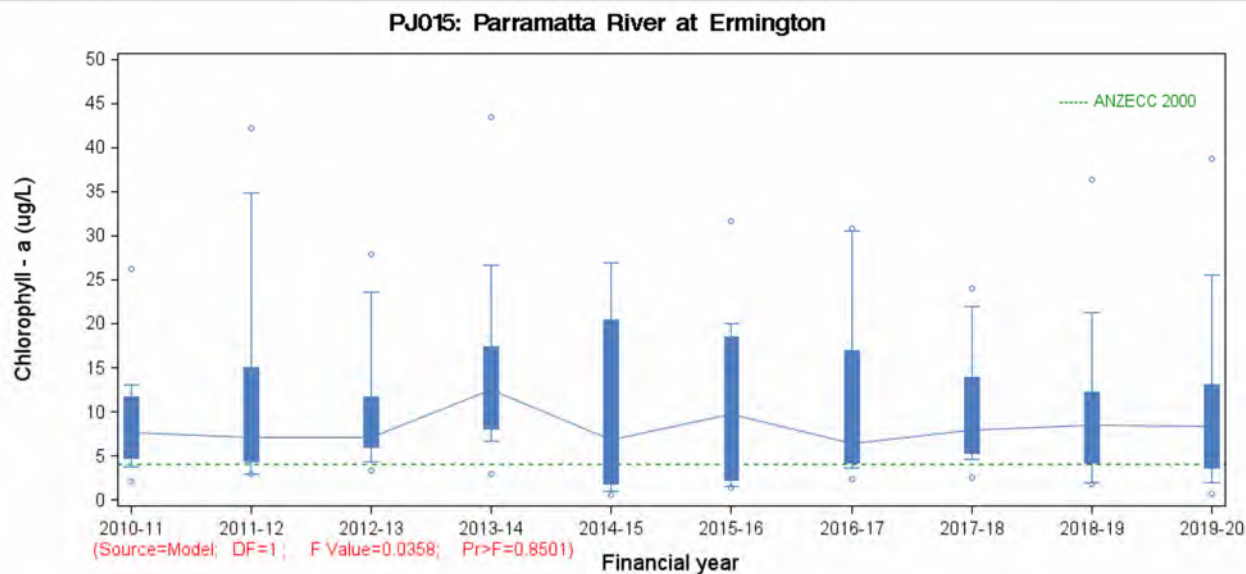
Sampling site	Sampling date	Enterococci (cfu/100ML)	Conductivity (µS/cm)	72 hours rain ≤2 mm	Station no	Station name
Port Kembla Beach	9-Dec-19	39	54100	0	68110	Berkeley (Northcliffe Drive)
	15-Dec-19	70	54200	0		
	14-Mar-20	210	53700	1.2		
	25-May-20	47	54600	1.2		
Ramsgate Baths	28-Jan-20	130	52900	0	66058	Sans Souci (Public School
Rose Bay Beach	4-May-20	140	53800	0	66098	Rose Bay (Royal Sydney Golf Club)
Shelly Beach (Manly)	9-Aug-19	94	55000	0	66126	Collaroy (Long Reef Golf Club)
	16-Jan-20	100	54400	0		
Silver Beach	10-Oct-19	60	53400	2	66058	Sans Souci (Public School
	11-Nov-19	100	53600	0		
South Curl Curl Beach	6-Sep-19	53	54100	0	66126	Collaroy (Long Reef Golf Club)
	15-Oct-19	39	54200	1		
	9-Dec-19	60	54400	0		
	13-Jan-20	53	54500	1.4		
South Maroubra Beach	23-Apr-20	230	55000	0	66052	Randwick (Randwick St)
	4-May-20	59	54300	0		
	15-Jul-19	50	54400	0		
	23-Apr-20	120	54900	0		
	4-May-20	45	55000	0		
South Steyne Beach	12-Jul-19	43	54400	0	66126	Collaroy (Long Reef Golf Club)
	9-Aug-19	200	54900	0		
	6-Sep-19	110	53900	0		
	23-Dec-19	41	54900	0		
	10-Jan-20	120	54400	0		
Tamarama Beach	16-Oct-19	120	54100	0.4	66098	Rose Bay (Royal Sydney Golf Club)
	24-Jan-20	39	54200	0		
	4-May-20	51	52100	0		
Thirroul Beach	1-Feb-20	41	53900	0	68108	Woonona (Popes Rd)
	1-Apr-20	48	53600	0.8	68228	Bellambi AWS
	7-Apr-20	41	54000	0		
Turimetta Beach	9-Aug-19	200	54300	0	66126	Collaroy (Long Reef Golf Club)
	23-Aug-19	39	54400	0		
Warriewood Beach	23-Aug-19	60	54500	0	66141	Mona Vale Golf Club
	6-Sep-19	95	54100	0.6		
Watsons Bay	24-Jan-20	58	53500	0	66099	Rose Bay (Royal Sydney Golf Club)
Whale Beach	6-Sep-19	53	53800	0	66128	Palm Beach (Sunrise Road)
	18-Jun-20	40	55800	1.2		
Woodford Bay	7-Aug-19	45	53100	0	66034	Abbotsford (Blackwall Point Rd)
Yarra Bay	28-Jan-20	76	53000	0.2	66037	Sydney Airport AMO

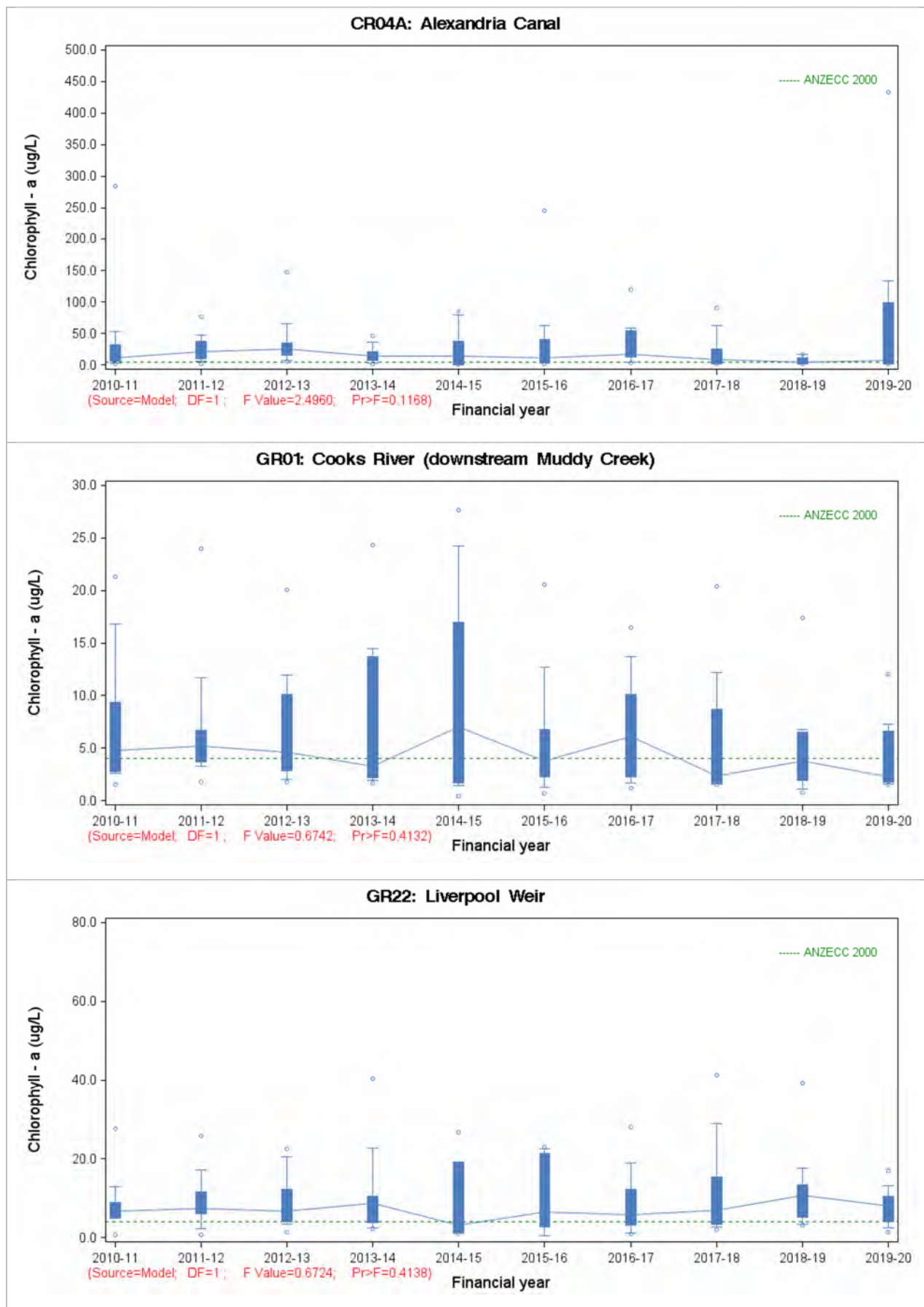
Appendix I : Chlorophyll-a trends at estuarine sites

Port Jackson

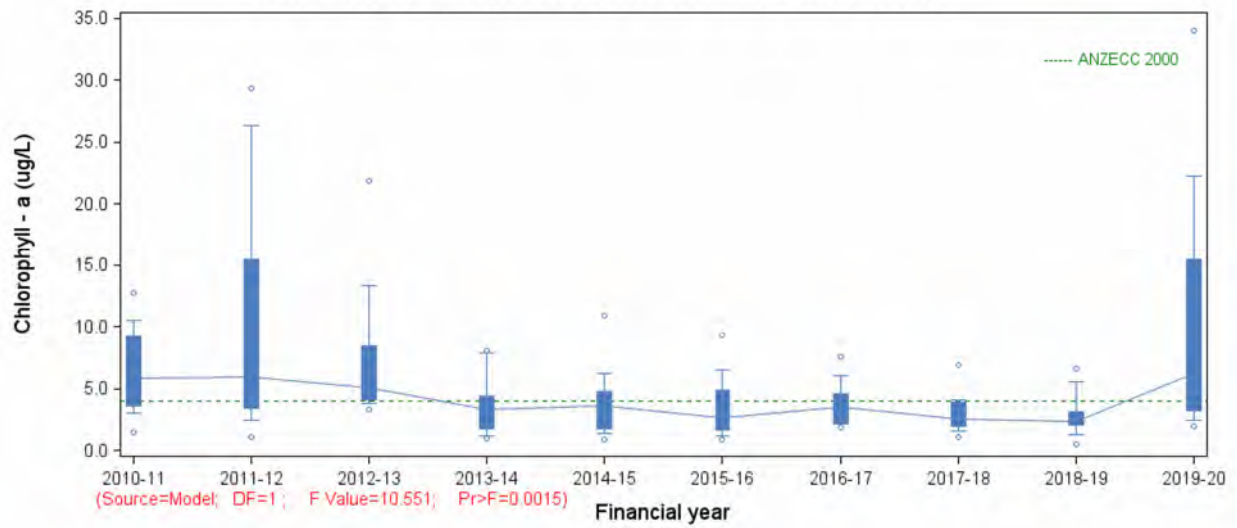




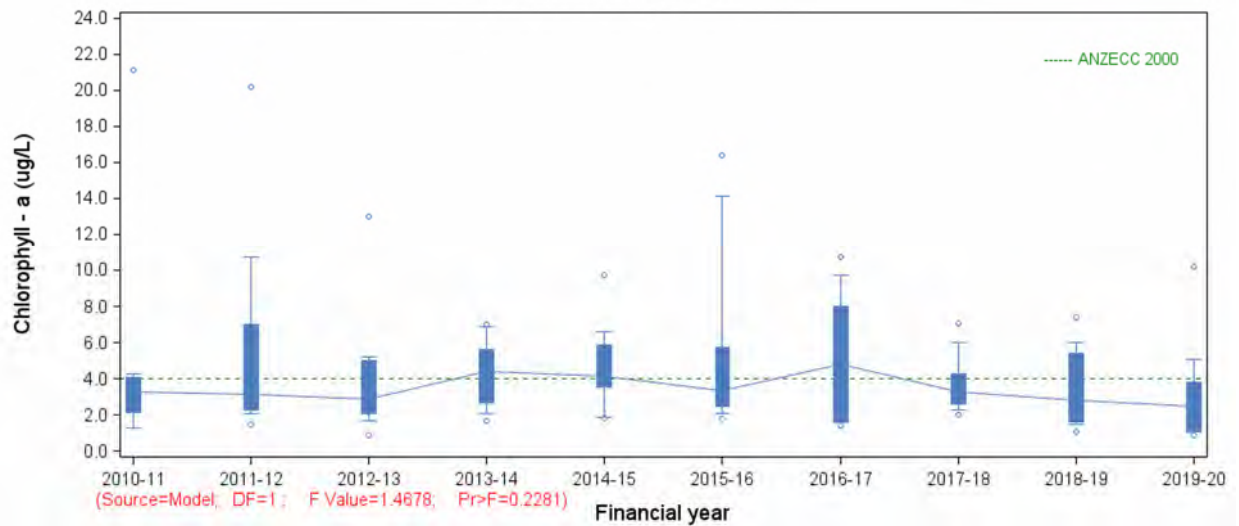




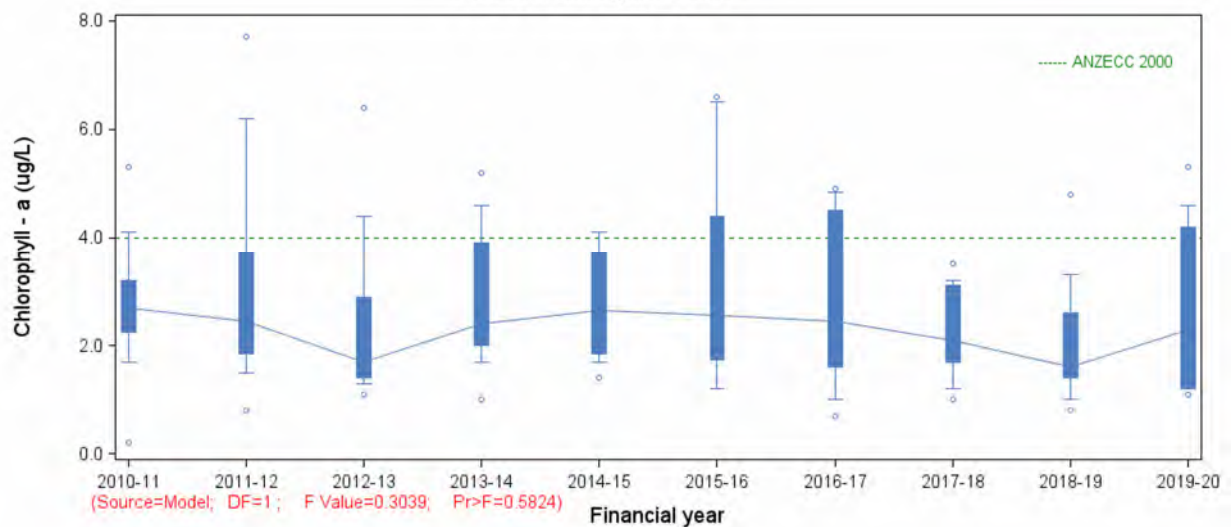
GR19: Upper Georges River (downstream of Harris Creek)

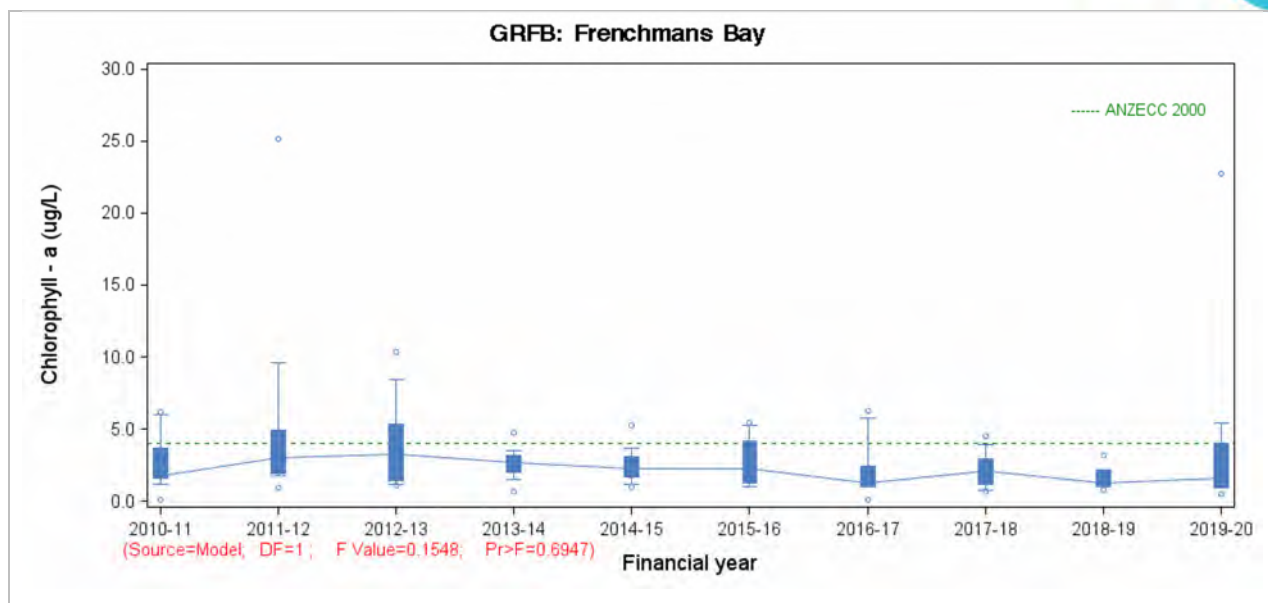


GROB: Oatley Baths

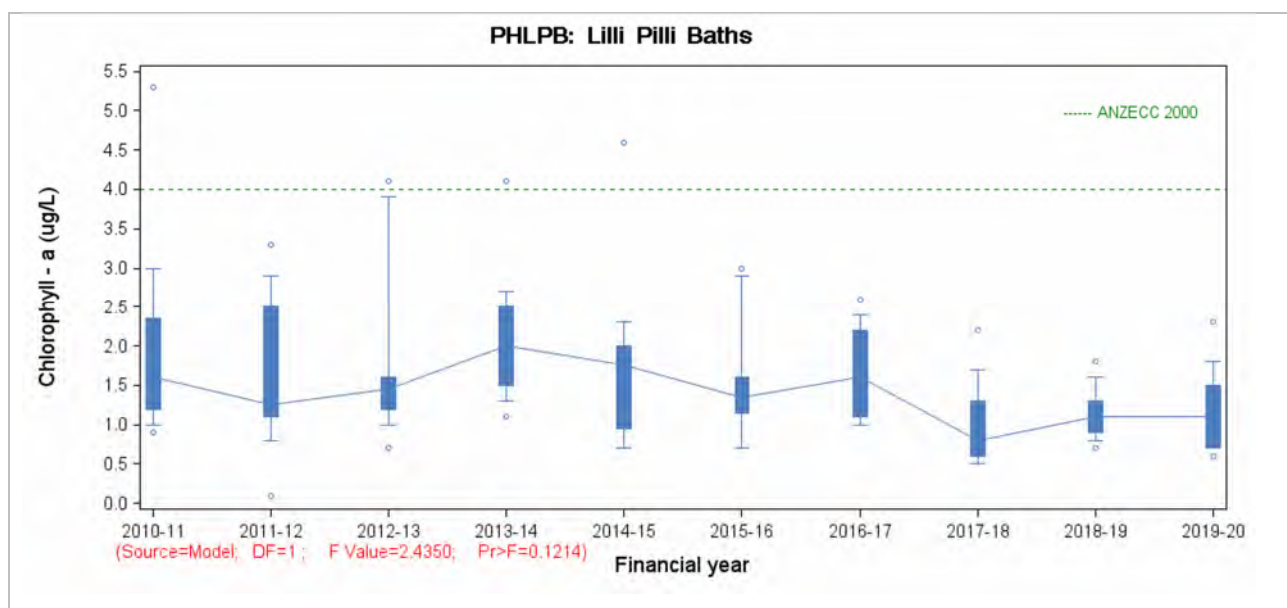


GRRB: Ramsgate Baths

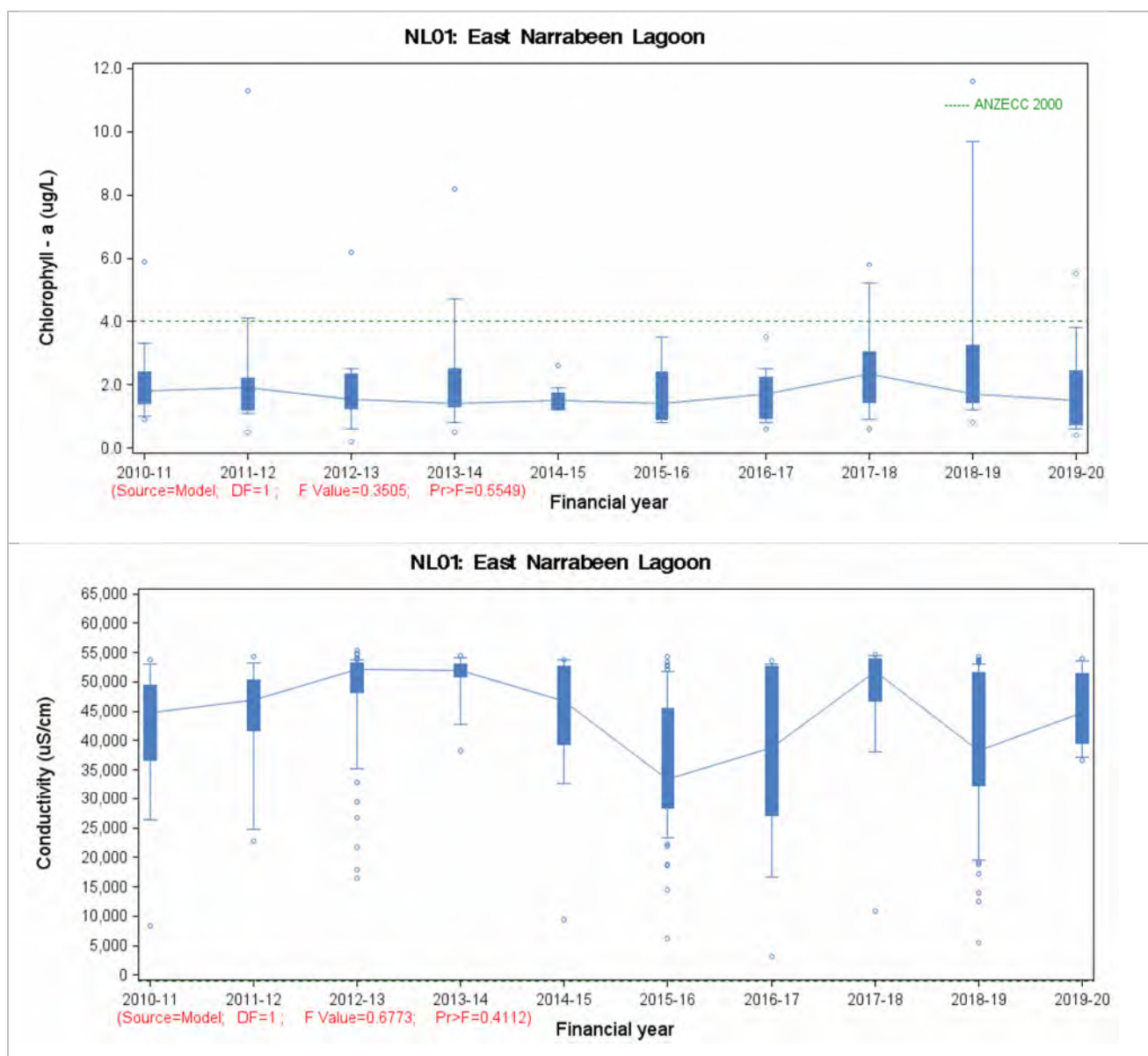


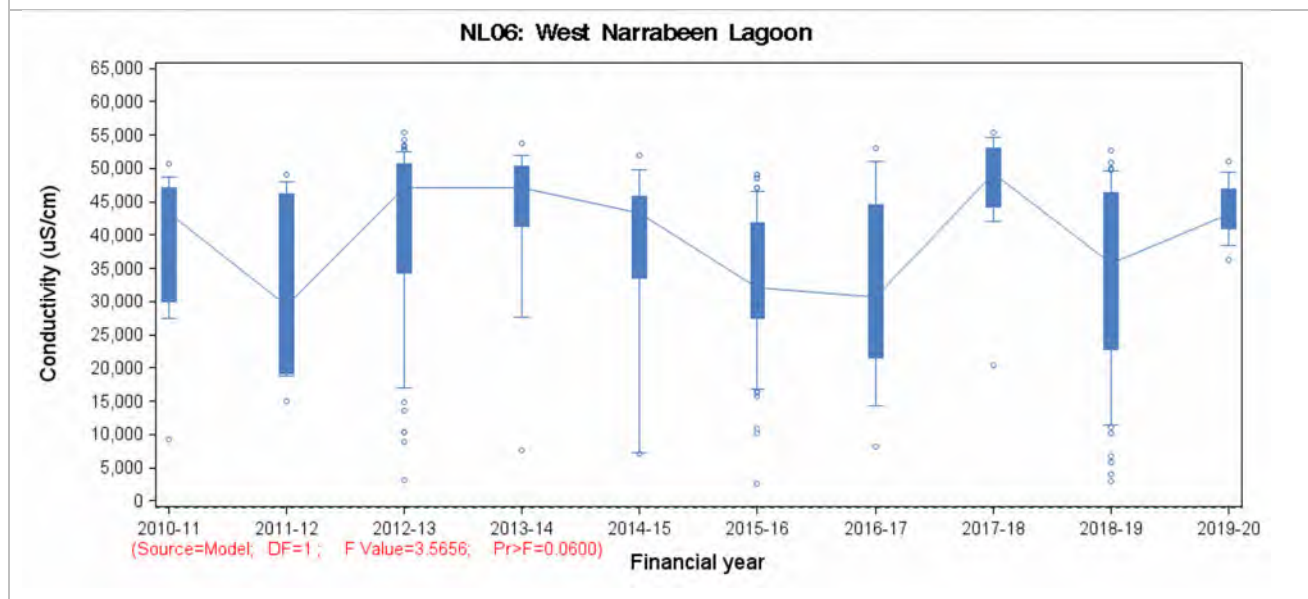
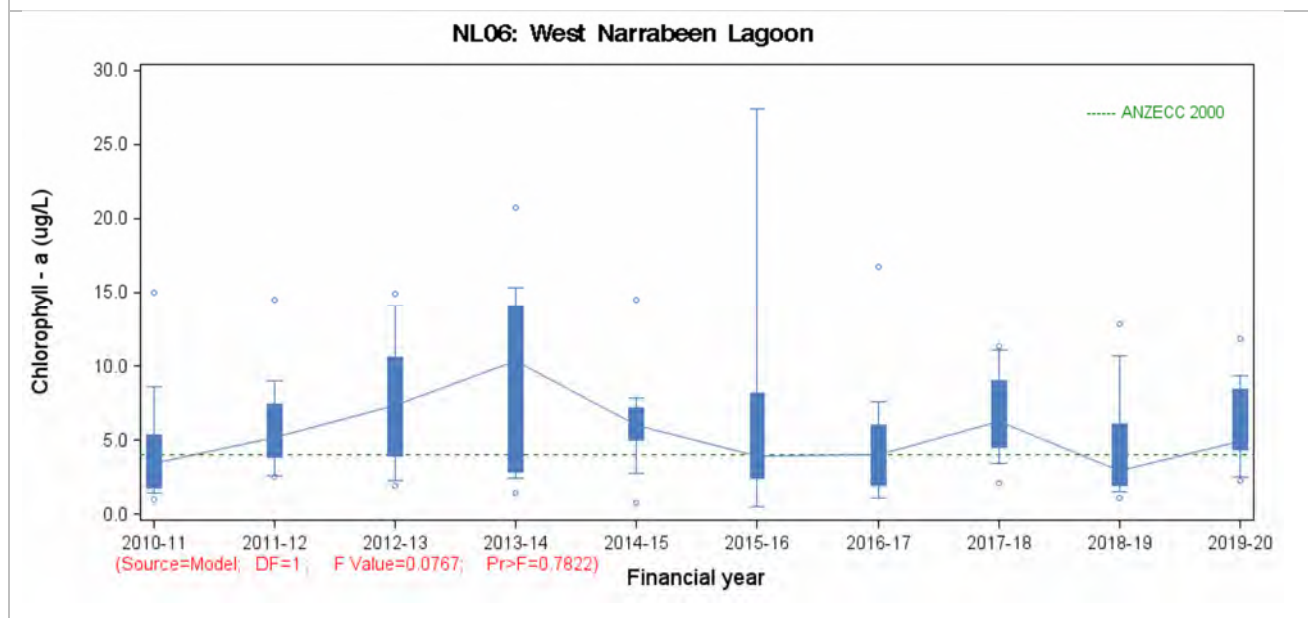
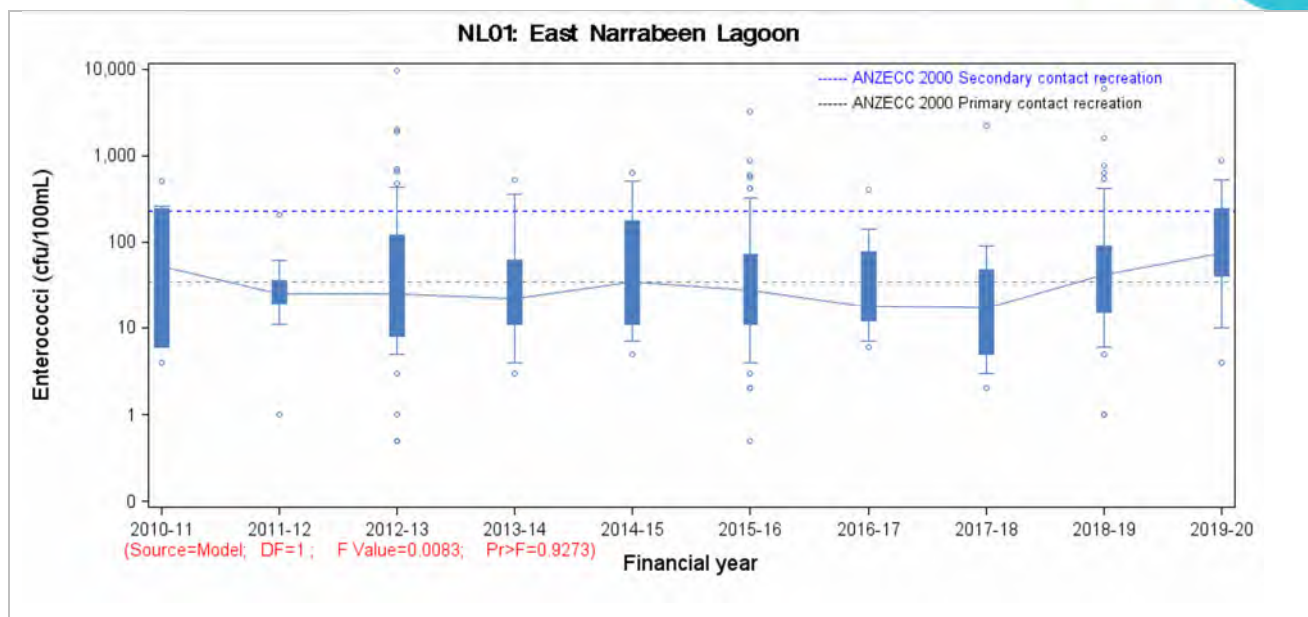


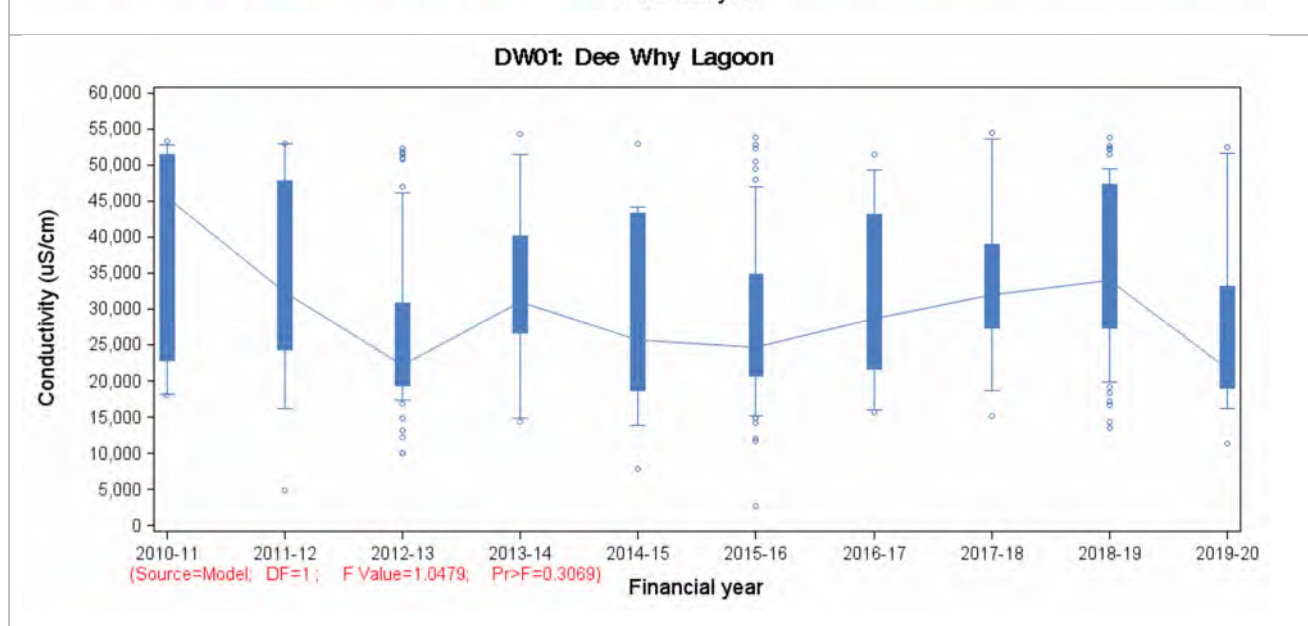
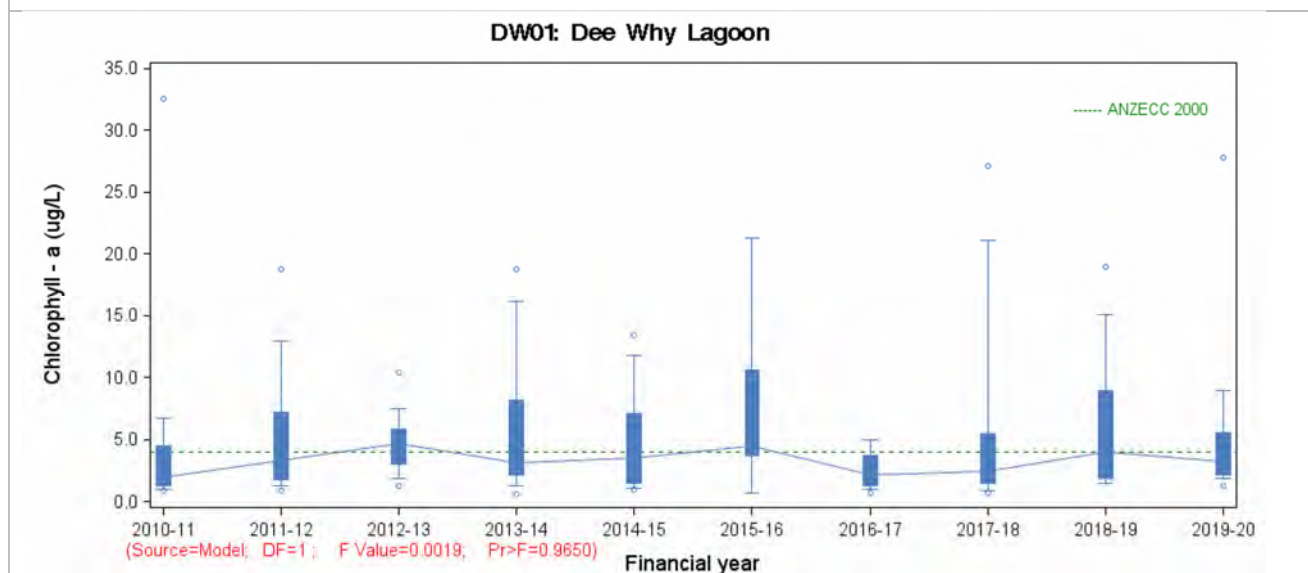
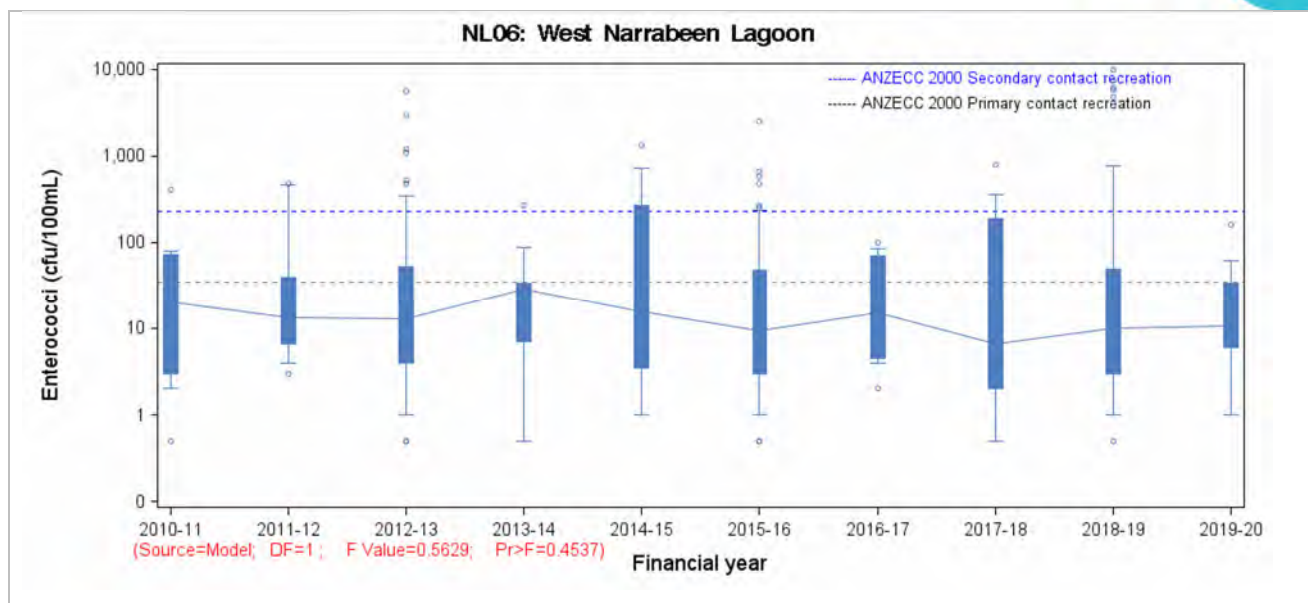
Port Hacking

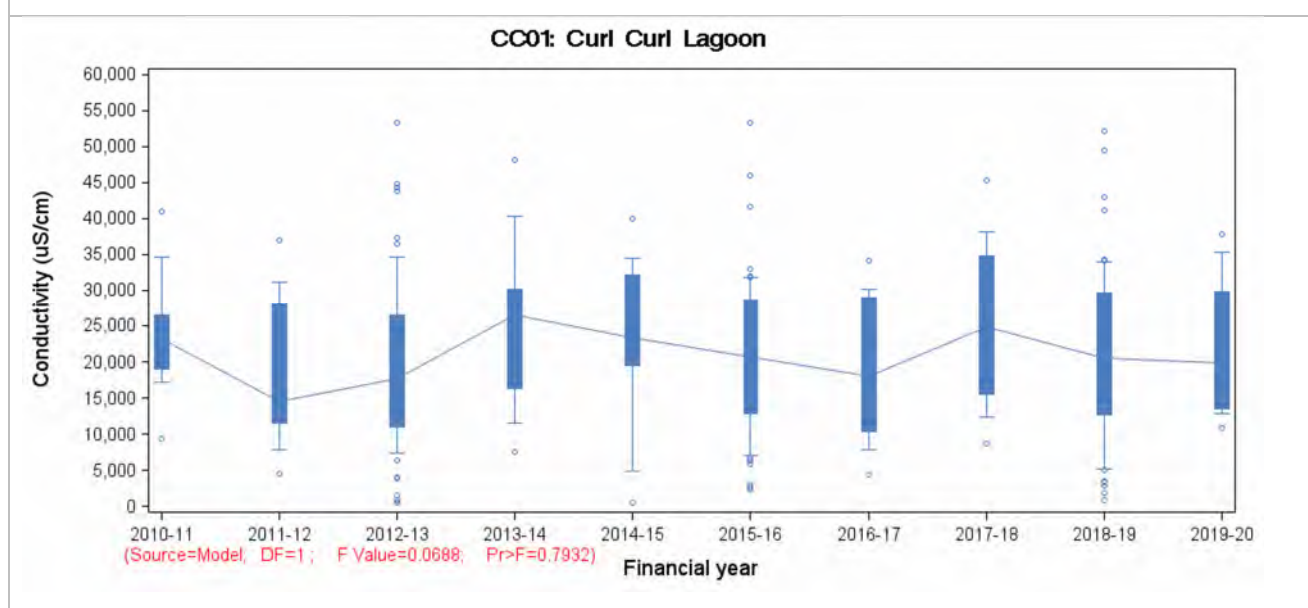
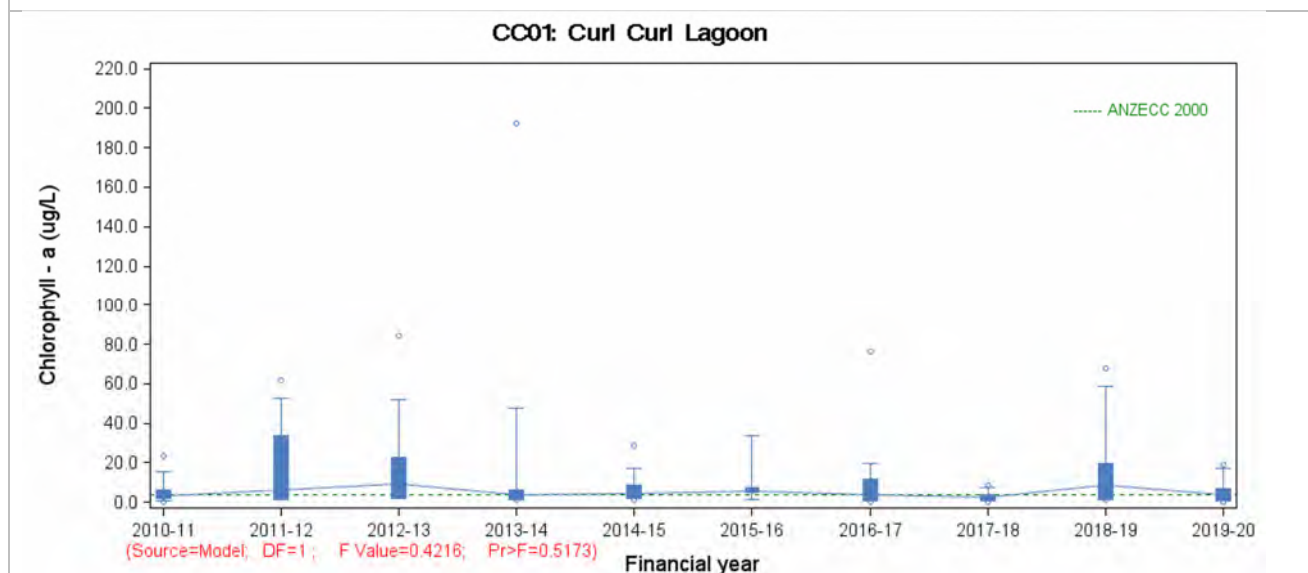
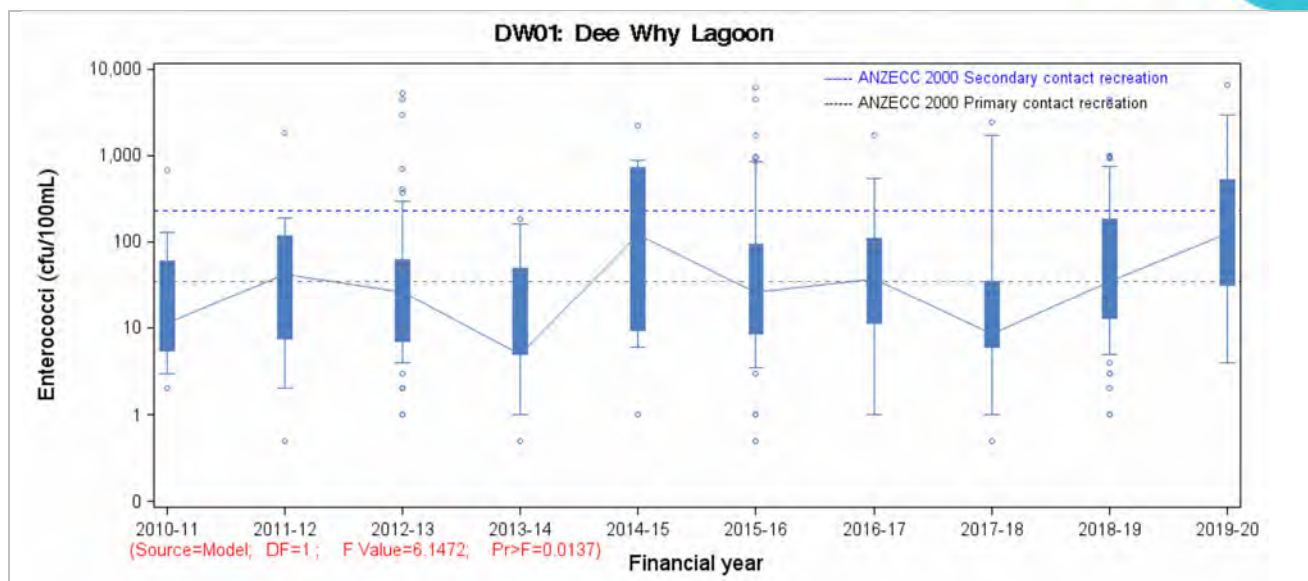


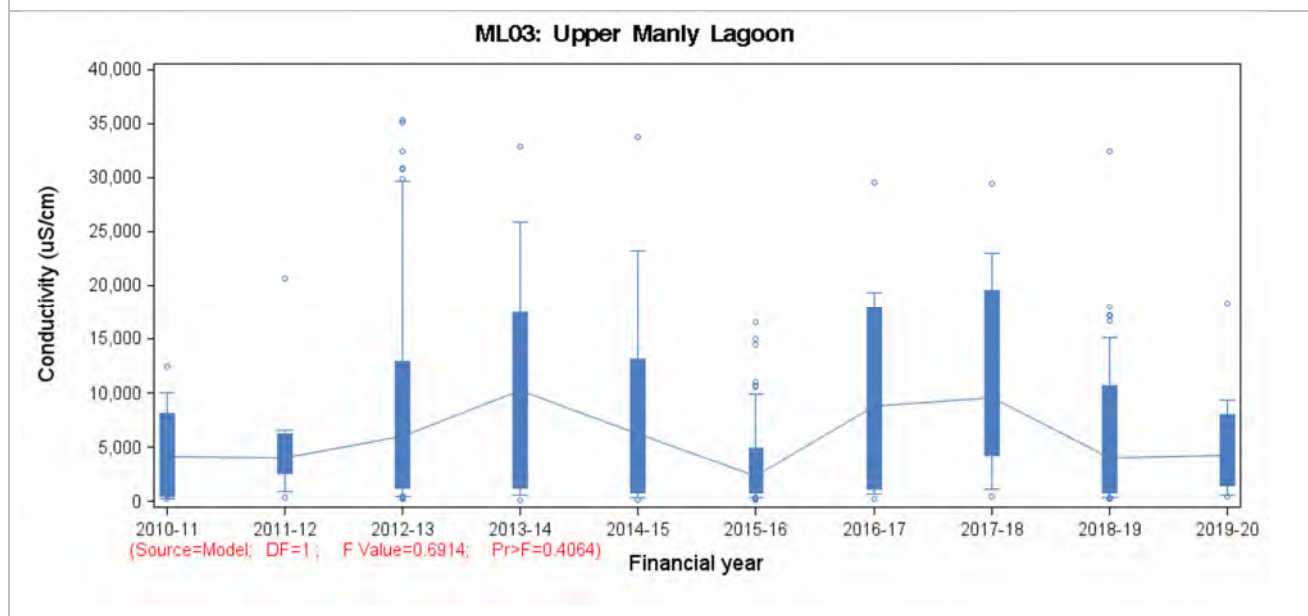
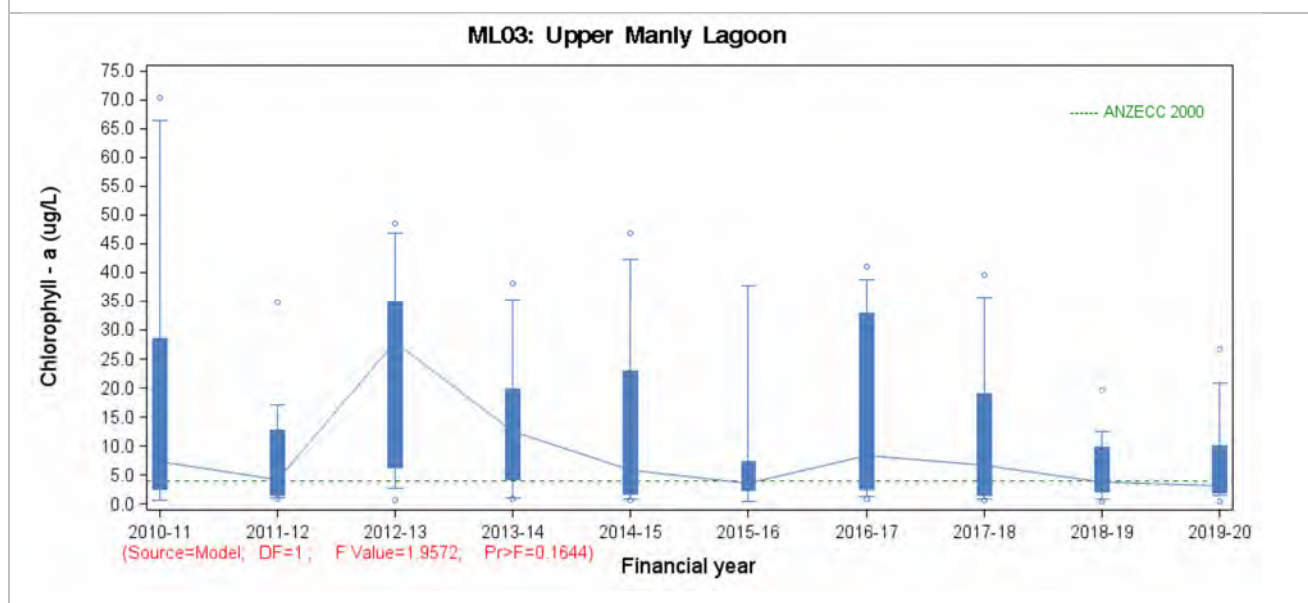
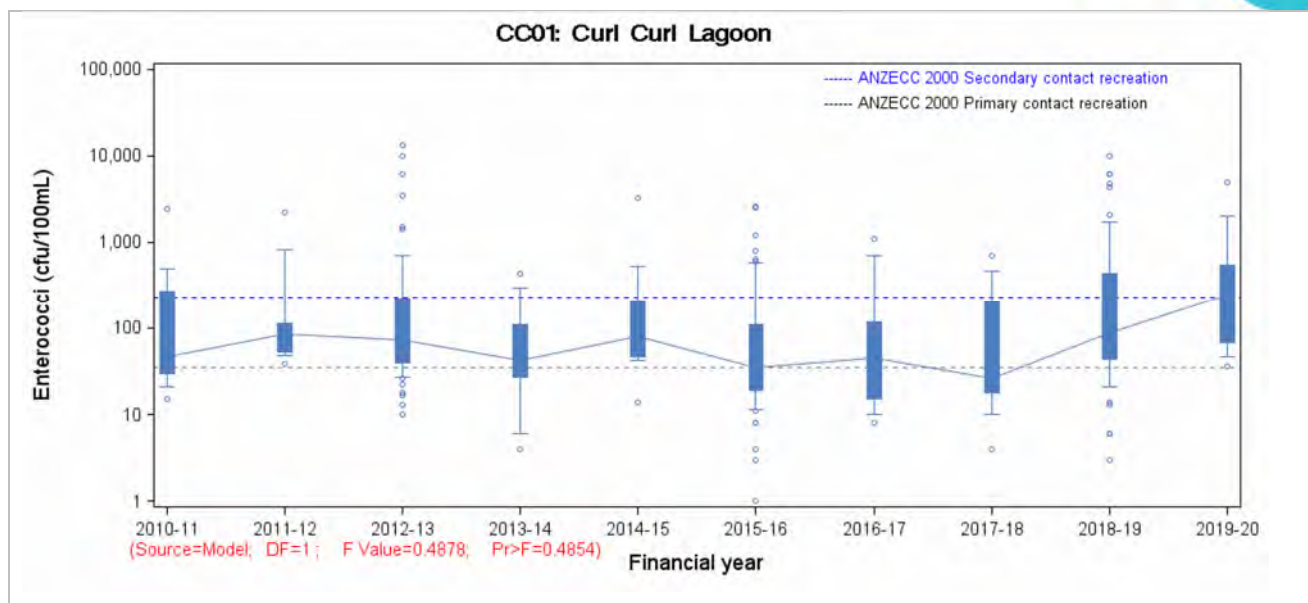
Appendix J : Water quality trends in lagoons

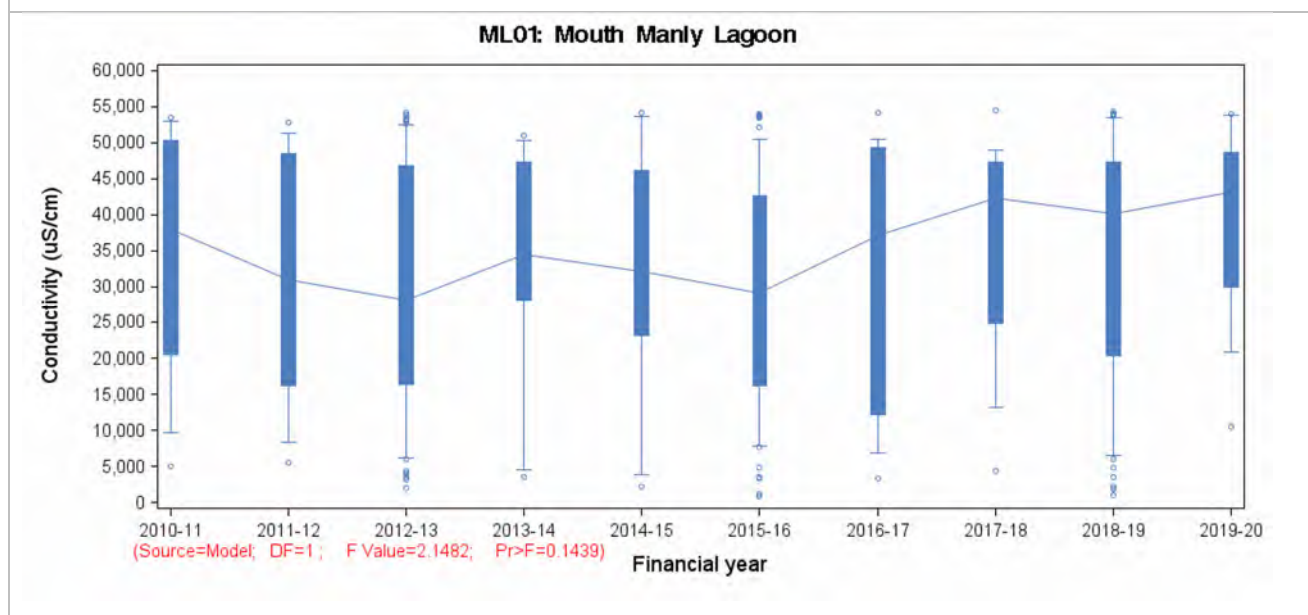
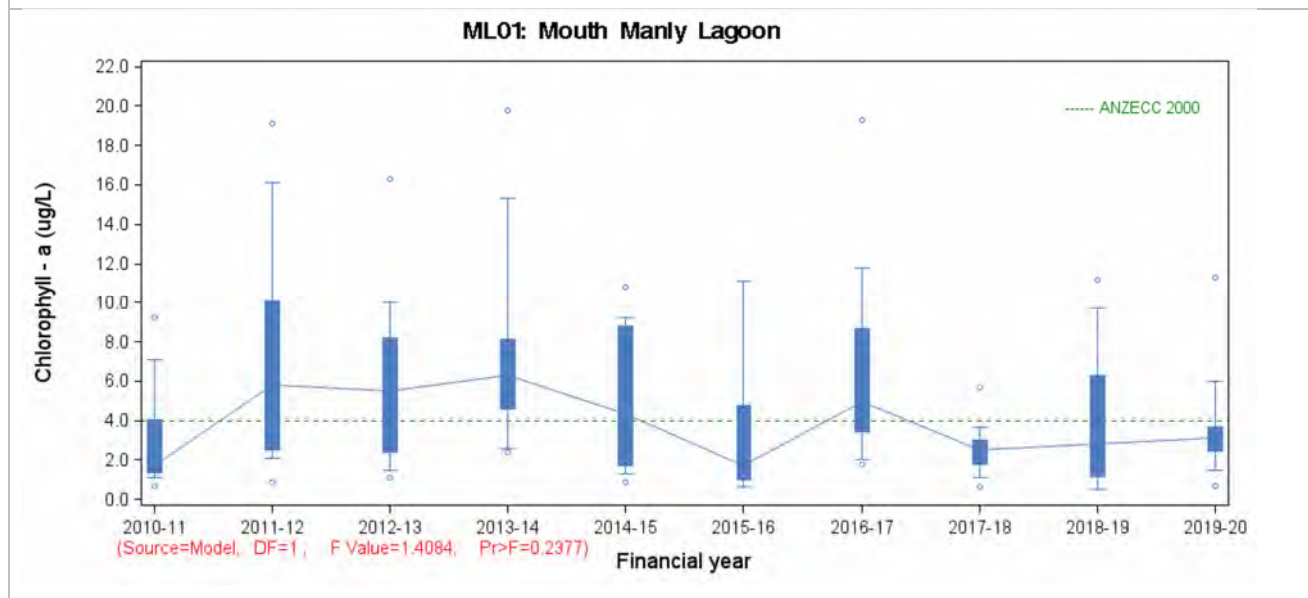
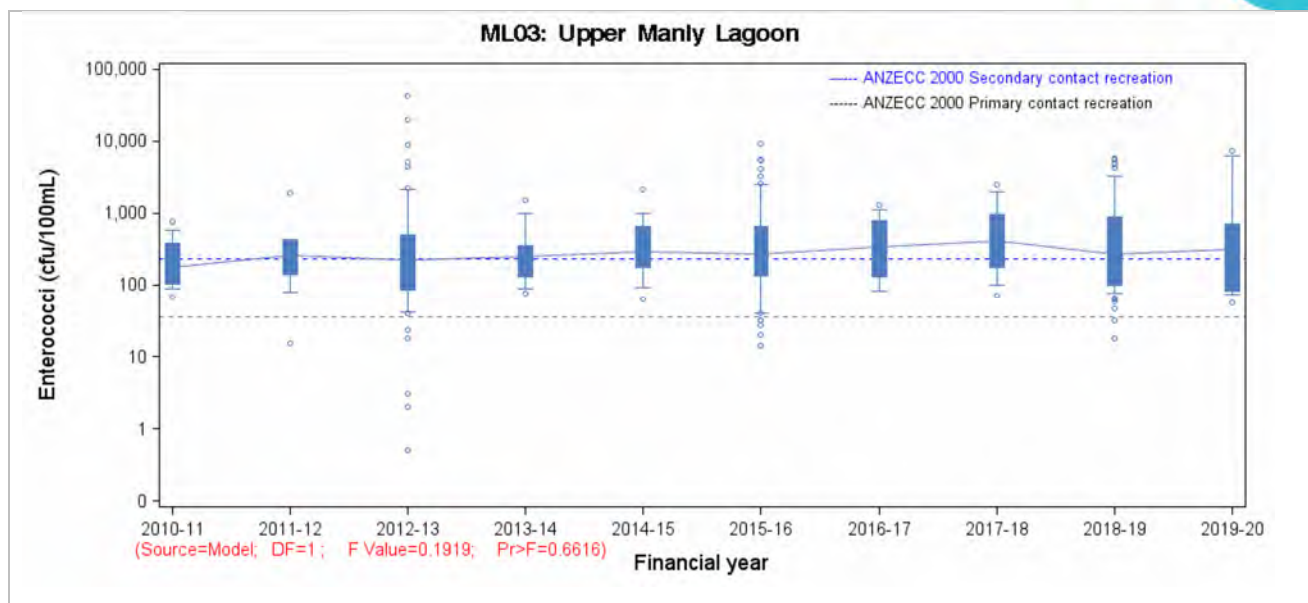


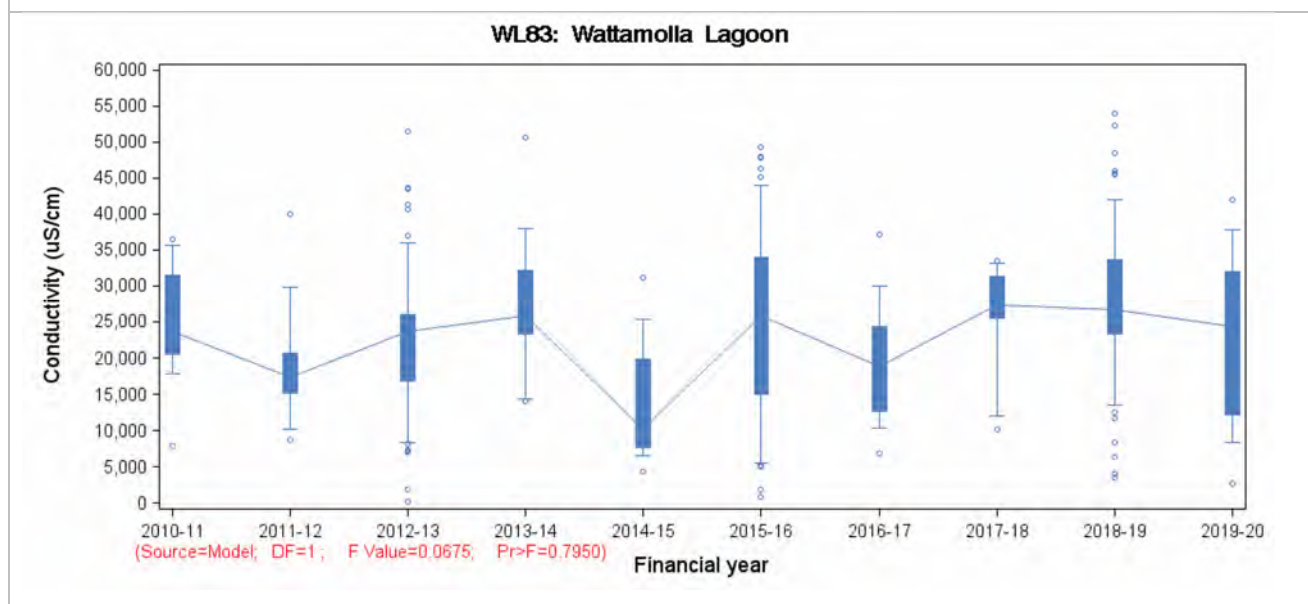
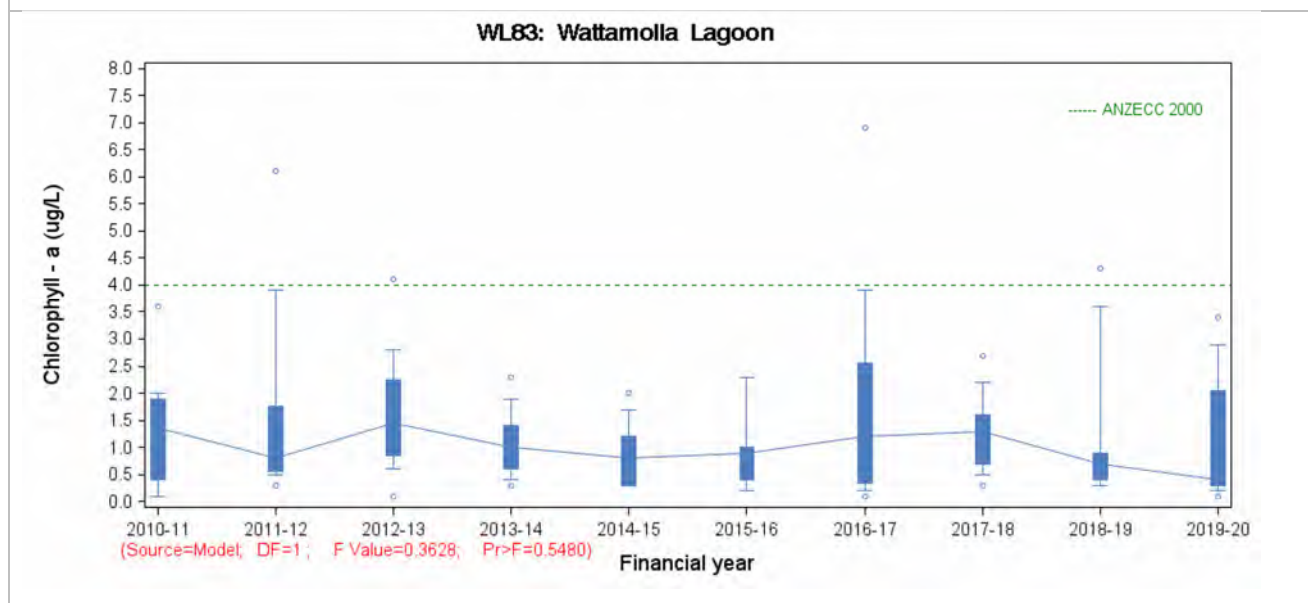
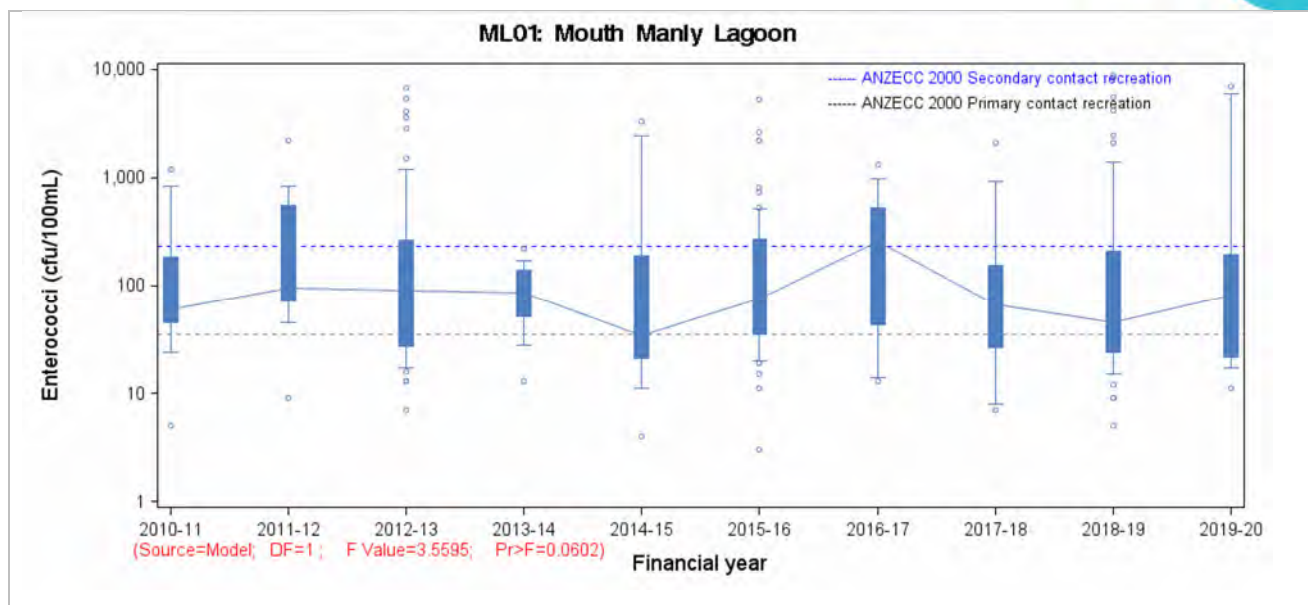


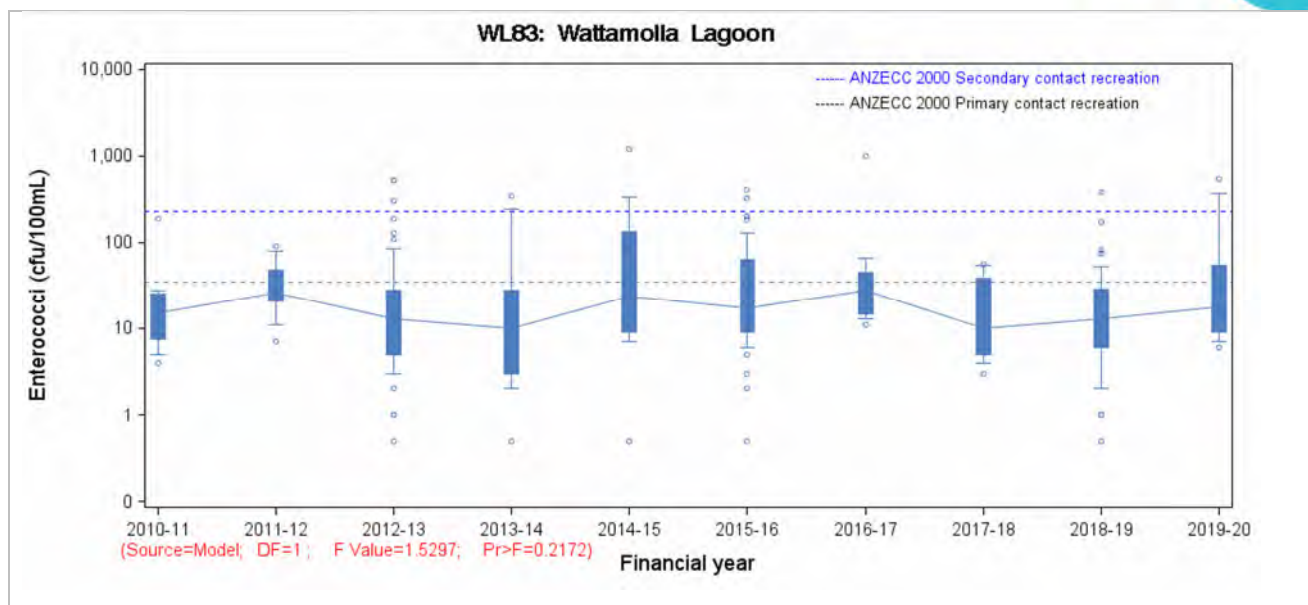














Appendix K : Intertidal communities

– Shoreline outfalls

Monitoring of rocky-intertidal communities under the shoreline outfall program assesses the potential ecological impact from the Shellharbour WWTP which discharges to the nearshore ocean environment. The structures of natural communities (without anthropogenic impacts) from two control sites were used in assessment of the Shellharbour outfall (impact) site (Volume 1 Figure 2-16). The Shellharbour outfall site is situated about 2 km north of the two control sites. The control sites were situated about 400 m apart. Shellharbour was the only WWTP that was measured under this program, as health and safety risks precluded access to intertidal rock platforms near the four other nearshore ocean outfall locations.

Rocky-intertidal communities are comprised of macro algae and macro invertebrate animals. These organisms will also colonise a variety of anthropogenic structures such as breakwaters, jetties, docks, groynes, dykes and seawalls (Crowe et al. 2000). Wave exposure is known to influence distribution and abundance of rocky-intertidal communities between exposed headlands and sheltered bays or inlets (Crowe et al. 2000). To control this natural influence, sites were selected that had similar levels of wave exposure. Rocky-intertidal community structure was monitored from wave-exposed ocean headland locations on naturally occurring rock platforms that could be safely accessed at low tide.

At each site, community composition and enumeration were recorded yearly during the period of late winter to late spring. Monitoring in this period reduces the influence of annual recruitment of most species of settling larvae that mainly happens in summer to autumn. Photographs of a 0.25 m² quadrat were taken within two hours either side of low tide. To help encapsulate variation between sites and across years, 14 randomly selected 0.25 m² quadrats were photographed between the low and high tide marks in the mid-littoral zone at each site visit. Using these photographs, counts were recorded for macro invertebrate taxa and estimates of percentage cover were made for macro algae. The taxonomic level recorded was based on morphological characteristics that could be seen with the naked eye and the level recorded is shown in the SIMPER 2019 output (Table K-2). Identification of macro invertebrate taxa and macro algae was checked against taxonomic works of Edgar (1997) and Dakin (1987).

Shoreline outfall discharges with documented measurable impacts on intertidal community structure are typically limited in spatial extent from 100 to 300 m (Fairweather 1990 and AWT 1998). These intertidal community structures were dominated by extensive covers of green macro algae. A pictorial example of a localised spatial impact of about 50 m² (Figure K-1) was formerly seen at Barrack Point outfall in 2001. At that time, an extensive cover of green macro algae occurred with few invertebrates (EP Consulting 2003). This was prior to upgrade works conducted at the Shellharbour WWTP in the early to mid-2000's.

The Bray-Curtis resemblance measure is focused on compositional changes in taxa identities (Anderson and Walsh 2013). As such, this is an appropriate choice since we understand the former measurable impact from near shore wastewater discharge at Shellharbour did cause a change in the composition of the intertidal rock platform community.

The PERMANOVA routine is designed to test whether it is reasonable to consider the existence of pre-defined groups given overall variability (Anderson et al. 2008).

An asymmetrical permutational multivariate analysis of variance test (PERMANOVA) was conducted with 'Control and Impact' locations treated as a fixed factor. 'Sites' were nested within 'Control and Impact', with 'Sites' treated as a random factor. The outfall site was the only site under the Impact location and the two sites were under the Control locations. A fourth root transformation was applied to the data prior to a Bray-Curtis dissimilarity matrix being constructed. This matrix was the basis for PERMANOVA testing with 9999 permutations run under a reduced model, with conservative Type III sums of squares inspected to base hypothesis decisions upon.

Asymmetrical PERMANOVA indicated there was no significant difference between 'Control and Impact' locations for the 2019 survey (Table K-3).

SIMPER analysis reflected a community structure dominated by invertebrates with a lesser contribution of macro algae at all three locations including the outfall location (Table K-4). The picture of the outfall site in 2019 (Figure K-1) reflects invertebrate dominance seen in SIMPER results, which is different to the green algal dominance recorded in 2001 prior to WWTP upgrade works (Figure K-2).

In summary the multivariate analyses of community structure of 2019 morphologically based intertidal rock platform community data suggested there was no measurable impact in the intertidal rock platform community near the outfall at Barrack Point from wastewater discharges from the Shellharbour WWTP. This outcome was supported by the differences apparent in the pictorial comparisons of 2001 and 2019. Context of 2019 data to the broader data collected back to 2008 is provided under the 2008 to 2019 data analysis below.

Table K-1 Asymmetrical PERMANOVA of 2019 intertidal assemblages

Permutational MANOVA

Sums of squares type: Type III (partial)

Fixed effects sum to zero for mixed terms

Permutation method: Permutation of residuals under a reduced model

Number of permutations: 9999

Factors

Name	Type	Levels
Control / Impact	Fixed	2
Site	Random	3

PERMANOVA table of results

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms	P(MC)
Control / Impact	1	13024	13024	2.4238	0.3349	3	0.2108
Site(Control / Impact)	1	5373.5	5373.5	5.7498	0.0028	9958	0.0019
Res	39	36447	934.54				
Total	41	54845					

Estimates of components of variation

Source	Estimate	Sq.root
S(Control / Impact)	409.87	20.245
V(Site(Control / Impact))	317.07	17.806
V(Res)	934.54	30.57

Table K-2 SIMPER 2019 - intertidal assemblages by site

Control site-1 – 2019 Average sample similarity: 59%

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Nerite (Nertidae <i>Nerita</i>)	2.18	20.32	4.48	34.34	34.34
Conniwinks (Lottorinidae <i>Bembicium</i>)	1.78	17.68	5.24	29.86	64.20
Periwinkles (Littorinidae <i>Nodilitorina</i>)	1.42	8.33	0.74	14.07	78.27
Brown algae (Phaeophyta)	1.33	4.81	0.48	8.12	86.39
False limpets & rock limpets (Patellogastropoda)	0.72	3.07	0.51	5.18	91.57
Zebra top shell (Trochidae <i>Austrocochlea</i>)	0.70	2.62	0.53	4.42	95.99
Barnacles (Cirripedia)	0.97	2.37	0.41	4.01	100.00

Control site-2 – 2019 Average sample similarity: 52%

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Barnacles (Cirripedia)	4.69	19.78	1.53	38.38	38.38
Periwinkles (Littorinidae <i>Nodilitorina</i>)	1.90	8.08	0.67	15.69	54.07
Nerite (Nertidae <i>Nerita</i>)	1.58	7.19	1.15	13.95	68.02
Conniwinks (Lottorinidae <i>Bembicium</i>)	1.51	6.25	0.95	12.13	80.15
Brown algae (Phaeophyta)	1.87	6.12	0.70	11.89	92.03
Zebra top shell (Trochidae <i>Austrocochlea</i>)	0.81	1.91	0.44	3.71	95.74
False limpets & rock limpets (Patellogastropoda)	0.66	1.77	0.54	3.43	99.17
Oyster Borer (Muricidae <i>Morula marginalba</i>)	0.34	0.43	0.26	0.83	100.00

Outfall site – 2019 Average sample similarity: 59%

Species	Av.Abund	Av.Sim	Sim/SD	Contrib%	Cum.%
Conniwinks (Lottorinidae <i>Bembicium</i>)	2.40	15.38	4.02	26.18	26.18
False limpets & rock limpets (Patellogastropoda)	1.90	10.77	3.09	18.33	44.52
Zebra top shell (Trochidae <i>Austrocochlea</i>)	2.18	8.70	1.09	14.81	59.33
Red Algae (Rhodophyta)	2.28	7.40	0.78	12.60	71.93
Barnacles (Cirripedia)	1.40	4.41	0.74	7.51	79.44
Oyster Borer (Muricidae <i>Morula marginalba</i>)	0.88	3.74	0.95	6.36	85.81
Periwinkles (Littorinidae <i>Nodilitorina</i>)	1.11	3.22	0.53	5.48	91.29
Green Algae (Chlorophyta)	1.40	3.05	0.54	5.19	96.48
Brown algae (Phaeophyta)	0.86	1.32	0.33	2.26	98.74
Nerite (Nertidae <i>Nerita</i>)	0.41	0.74	0.35	1.26	100.00



Figure K-1 Barrack Point with a healthy intertidal rock platform community in 2019



Figure K-2 Barrack Point (in 2001) with an unhealthy intertidal rock platform community impacted by wastewater discharges from the Shellharbour WWTP prior to upgrade in the early to mid 2000's

Intertidal communities Shellharbour 2008 to 2019

Inclusion of yearly replicate samples from 2008 to 2019 allowed the factor 'Time' to be included in the above asymmetrical permutational analysis of variance test (PERMANOVA). Time was comprised of 2008, 2009, 2010, 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018 and 2019 surveys, which were conducted at varying times through late winter to late spring.

Asymmetrical PERMANOVA indicated there was no significant difference between 'Control and Impact' locations for the 2008 to 2019 period (Table K-3). However, differences between sites through time were indicated as significant results were returned for the 'Site (Control and Impact)' and 'Site (Control / Impact) x Time' factors (Table K-3).

The non-metric multidimensional scaling (nMDS) ordination routine of PRIMER was used to produce two and three dimensional ordination plots. In these plots the relative distance between samples is proportional to the relative similarity in taxonomic composition and abundance – the closer the points on the graph the more similar the community (Clarke 1993). That is, site samples with similar taxa lay closer together and site samples with a differing taxon composition lie farther apart. An unconstrained ordination procedure such as nMDS inevitably introduces distortion when trying to simultaneously represent the similarities between large numbers of samples in a few dimensions. The success of the procedure is measured by a stress value, which indicates the degree of distortion imposed. In the PRIMER software package a stress value of below 0.2 indicates an acceptable representation of the original data, although lower values are desirable. Where stress values are just above 0.2, the patterns displayed should be confirmed with other techniques such as PERMANOVA. The returned two-dimensional stress value was 0.22 and an improved lower stress value of 0.15 was observed for the three-dimensional ordination plot.

To understand the context of 2019 site data to that of previous years (2008 to 2018), site sample data were colour coded as shown in Figure K-3. Data patterns displayed in this two-dimensional nMDS ordination plot indicated 2008 to 2018 Control site-1 samples overlapped with 2008 to 2018 outfall site samples. The 2019 outfall samples also overlaid this mass of samples. While the Control site-1 samples from 2019 overlaid the agglomeration of Control site-1 2008 to 2018 samples. The 2019 Control-site 2 samples tended to spread from the edge of the agglomeration of Control site-2 2008 to 2019 indicating greater taxonomic variation to previous years. A three-dimensional nMDS ordination plot is presented in Figure K-4. It indicates a tighter agglomeration of samples than displayed in the two dimensional nMDS ordination plot in Figure K-3.

Under the nMDS routine, due to rank ordering of dissimilarities some detail can be hidden. This detail may be seen using a Principal Coordinates Analysis (PCO) routine as PCO is based upon original dissimilarities being projected onto axes in the space of the chosen resemblance measure (Anderson et al. 2008). As a check for any additional dimensionality in the multivariate data cloud, a PCO ordination plot was raised based on a fourth root transformation of the data and a Bray-Curtis resemblance measure. No additional dimensionality was indicated as the patterns between nMDS (Figure K-3, Figure K-4) and PCO ordination (Figure K-5) plots were very similar.

A Canonical Analysis of Principal Coordinates (CAP) ordination plot was also produced (Figure K-6). The CAP routine is designed to ask, 'Are there axes in the multivariate space that separate groups?' CAP is designed to purposely seek out and find groups even if differences occur in obscure directions and may not have been apparent from nMDS or PCO plots that provide views of the multivariate data cloud as a whole (Anderson et al. 2008). A similar pattern to that in the



nMDS (Figure K-3) and PCO (Figure K-5) ordination plots was displayed. This also suggested no hidden dimensionality, with good agreement between the nMDS, PCO and CAP ordination plots.

An additional run of the CAP routine was undertaken with placement of 2019 outfall samples onto the canonical axes of the existing CAP model from the initial run. Output from the second run indicated 2019 outfall samples were most similar to either the Outfall 2008 to 2018 samples or Control site 1 2008 to 2019 samples (Figure K-6). This result also reflected patterns displayed in the nMDS and PCO ordination plots (Figure K-4, Figure K-5 and Figure K-6).

The trend of taxonomic differences between sites situated close together on shorelines is known to occur and accounts for the differences between Control site-1 that is only 400 m from Control site-2 on the shoreline. It is mentioned by Underwood and Chapman (1998) who cite Underwood (1981) who states 'on exposed shores in New South Wales there are great differences in patterns of occupancy of space from one place to another not many metres away, even though these are not a function of gradients in wave action.'

In summary, a relatively stable equilibrium in rocky-intertidal community structure was indicated from these assessments of the 2008 to 2019 monitoring data at the three sites studied under the STSIMP. These results also suggest over the 2008 to 2019 period, no measurable impact had developed in the intertidal rock platform community near the outfall at Barrack Point from wastewater discharges from the Shellharbour WWTP as the community assemblage of the outfall site was very similar to Control site-1 for the 2008 to 2018 period. Results from Control site-2 represent natural variation in rocky-intertidal community structure that has been demonstrated to occur for closely spaced shoreline sites.

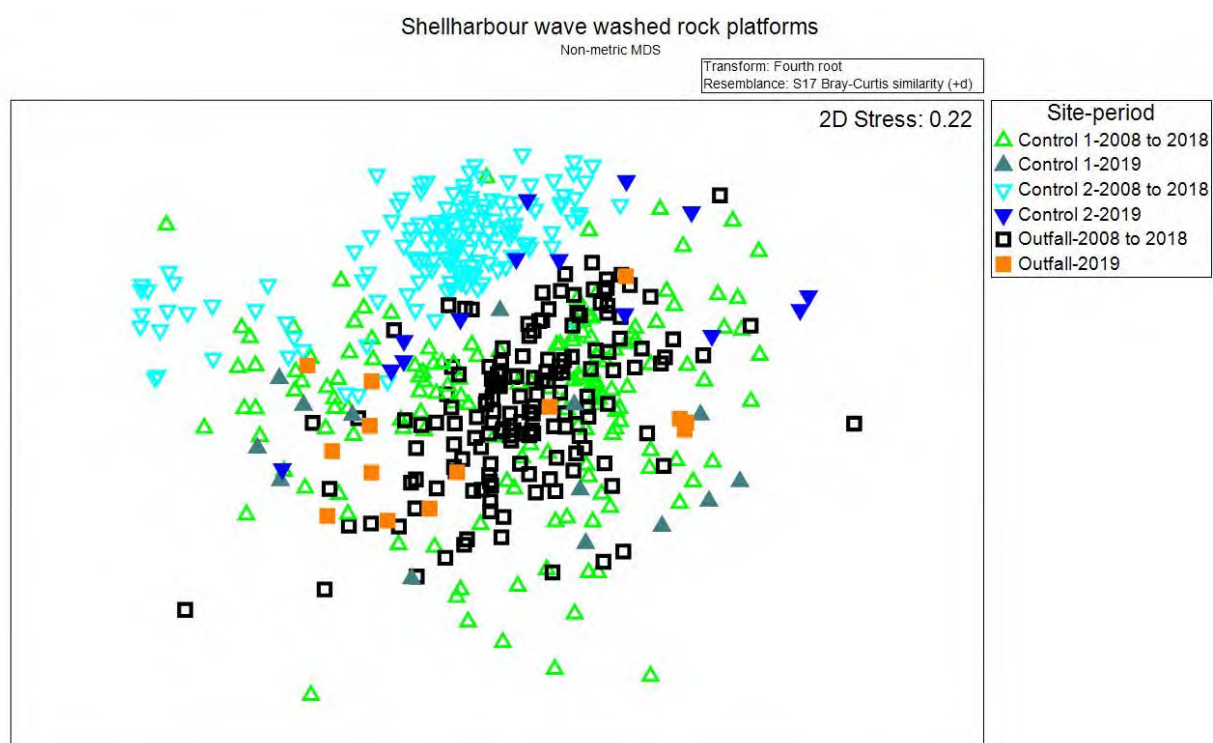


Figure K-3 Two-dimensional nMDS ordination plot of 2008 to 2019 intertidal rock platform community data

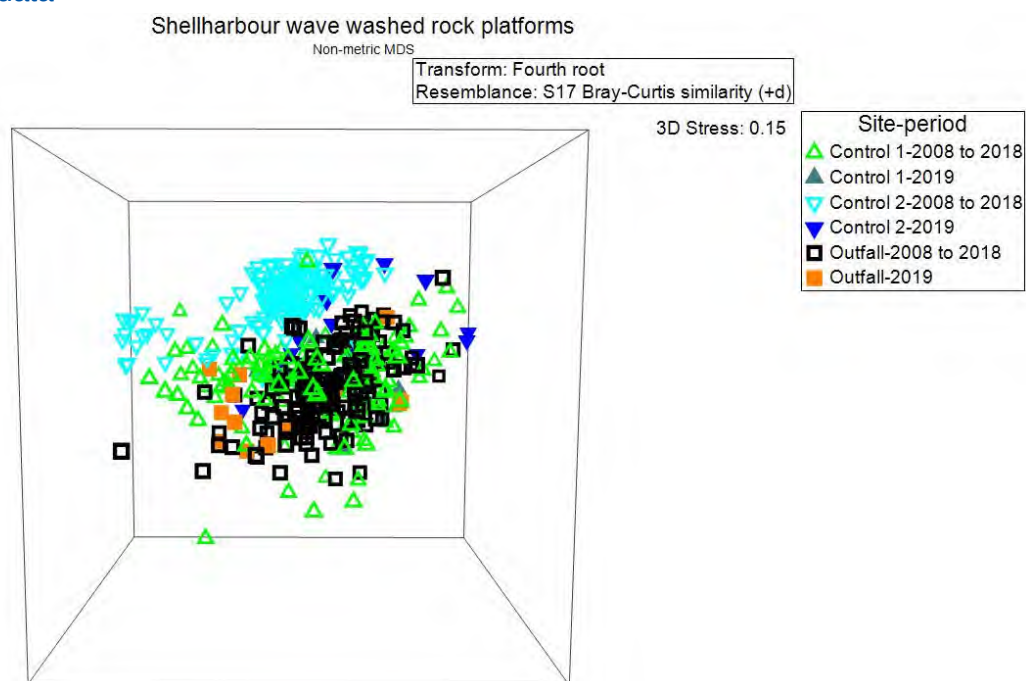


Figure K-4 Three-dimensional nMDS ordination plot of 2008 to 2019 intertidal rock platform community data

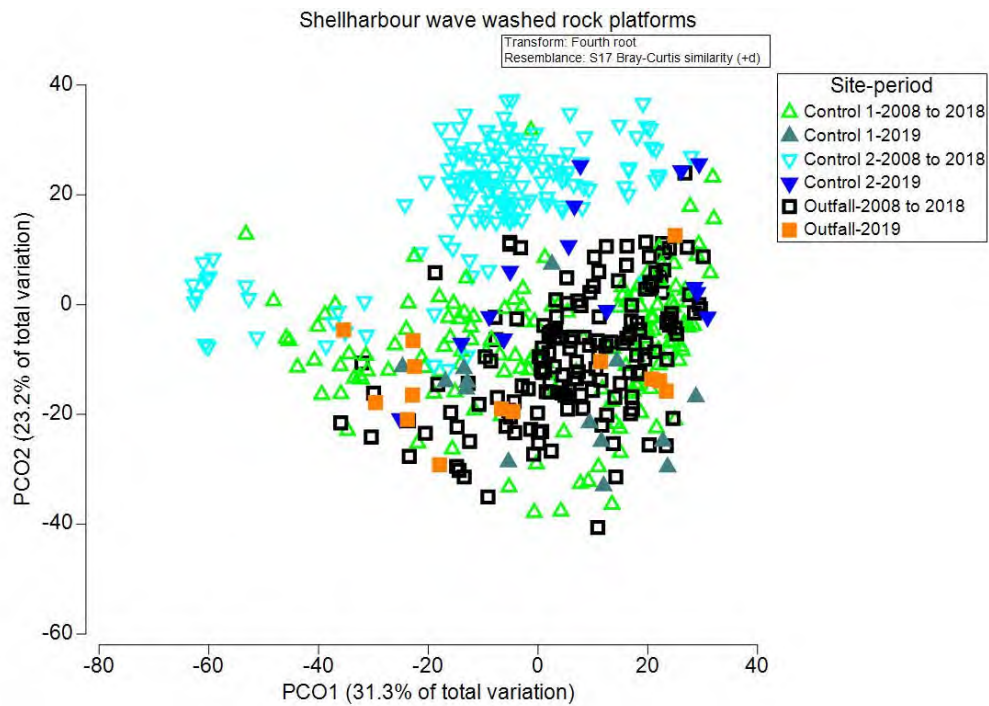


Figure K-5 PCO ordination plot of 2008 to 2019 intertidal rock platform community data - dimensional

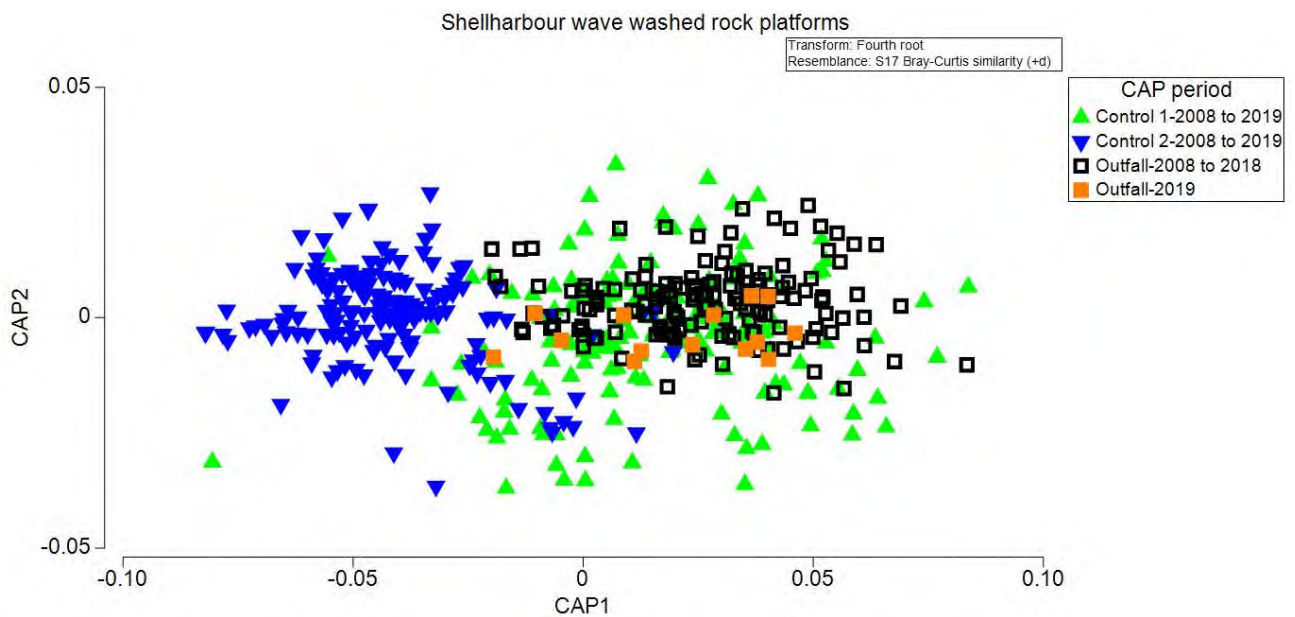


Figure K-6 CAP ordination plot of intertidal rock platform community data (2008 to 2018 for Control site 1 and Control site 2 and 2008 to 2018 outfall site) with 2019 outfall samples (orange squares) predicted

Table K-3 Asymmetrical PERMANOVA of 2008 to 2019 intertidal assemblages

Sums of squares type: Type III (partial)

Fixed effects sum to zero for mixed terms

Permutation method: Permutation of residuals under a reduced model

Number of permutations: 9999

Factors

Name	Type	Levels
Control / Impact	Fixed	2
Time	Fixed	12
Site	Random	3

PERMANOVA table of results

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms	P(MC)
Control / Impact	1	54135	54135	0.72584	0.6671	3	0.6036
Time	11	67867	6169.7	1.2567	0.1999	9911	0.2459
Site(Control / Impact)	1	73275	73275	101.58	0.0001	9950	0.0001
Control / ImpactxTime	11	48254	4386.7	0.89421	0.6668	9901	0.6372
TimexSite(Control / Impact)	11	53227	4838.8	6.7082	0.0001	9897	0.0001
Res	466	3.3614E+05	721.33				
Total	501	6.3919E+05					

Estimates of components of variation

Source	Estimate	Sq.root
S(Control / Impact)	-91.177	-9.5486
S(Time)	33.744	5.8089
V(Site(Control / Impact))	439.06	20.954
S(Control / ImpactxTime)	-27.814	-5.2739
V(TimexSite(Control / Impact))	298.31	17.272
V(Res)	721.33	26.858

Table K-4 CAP analysis of 2008 to 2018 intertidal assemblages with 2019 outfall site samples predicted

Factor level for new samples group: Outfall-2019

Number of samples: 488

Choice of m: 3

CANONICAL ANALYSIS

Correlations

Eigenvalue	Correlation	Corr.Sq.
1	0.8122	0.6597
2	0.25	0.0625

DIAGNOSTICS

m	prop.G	ssres	d_1^2	d_2^2	%correct
3	0.7144	1.2945	0.6597	0.0625	65.984

Cross Validation

Leave-one-out Allocation of Observations to Groups (for the choice of m: 3)

Classified

Orig. group	Control 1-2008 to 2019	Control 2-2008 to 2019	Outfall-2008 to 2018	Total	%correct
Control 1-2008 to 2019	75	18	75	168	44.643
Control 2-2008 to 2019	13	151	0	164	92.073
Outfall-2008 to 2018	54	6	96	156	61.538

Total correct: 322/488 (65.984%)

Mis-classification error: 34.016%

Individual samples that were mis-classified

Sample	Orig.group	Class.group
Control 1-2018-1	Control 1-2008 to 2019	Outfall-2008 to 2018
Control 1-2018-4	Control 1-2008 to 2019	Outfall-2008 to 2018
Control 1-2018-5	Control 1-2008 to 2019	Outfall-2008 to 2018
Control 1-2018-6	Control 1-2008 to 2019	Outfall-2008 to 2018
Control 1-2018-10	Control 1-2008 to 2019	Outfall-2008 to 2018
Control 1-2018-11	Control 1-2008 to 2019	Control 2-2008 to 2019
Control 1-2018-12	Control 1-2008 to 2019	Control 2-2008 to 2019
Control 1-2018-13	Control 1-2008 to 2019	Control 2-2008 to 2019
Control 1-2018-14	Control 1-2008 to 2019	Control 2-2008 to 2019
Control 1-2008-1	Control 1-2008 to 2019	Outfall-2008 to 2018
Control 1-2008-2	Control 1-2008 to 2019	Outfall-2008 to 2018
Control 1-2008-3	Control 1-2008 to 2019	Outfall-2008 to 2018
Control 1-2008-4	Control 1-2008 to 2019	Outfall-2008 to 2018
Control 1-2008-5	Control 1-2008 to 2019	Outfall-2008 to 2018
Control 1-2008-6	Control 1-2008 to 2019	Outfall-2008 to 2018
Control 1-2008-7	Control 1-2008 to 2019	Outfall-2008 to 2018
Control 1-2008-8	Control 1-2008 to 2019	Outfall-2008 to 2018
Control 1-2008-9	Control 1-2008 to 2019	Outfall-2008 to 2018
Control 1-2008-10	Control 1-2008 to 2019	Outfall-2008 to 2018
Control 1-2008-11	Control 1-2008 to 2019	Outfall-2008 to 2018
Control 1-2008-12	Control 1-2008 to 2019	Outfall-2008 to 2018
Control 1-2009-2	Control 1-2008 to 2019	Outfall-2008 to 2018
Control 1-2009-4	Control 1-2008 to 2019	Outfall-2008 to 2018
Control 1-2009-5	Control 1-2008 to 2019	Outfall-2008 to 2018
Control 1-2009-7	Control 1-2008 to 2019	Outfall-2008 to 2018
Control 1-2009-9	Control 1-2008 to 2019	Outfall-2008 to 2018
Control 1-2009-10	Control 1-2008 to 2019	Outfall-2008 to 2018
Control 1-2009-12	Control 1-2008 to 2019	Outfall-2008 to 2018
Control 1-2009-13	Control 1-2008 to 2019	Outfall-2008 to 2018

[illegible]

[illegible]

Outfall-2016-5	Outfall-2008 to 2018	Control 1-2008 to 2019
Outfall-2016-6	Outfall-2008 to 2018	Control 2-2008 to 2019
Outfall-2016-9	Outfall-2008 to 2018	Control 1-2008 to 2019
Outfall-2016-11	Outfall-2008 to 2018	Control 1-2008 to 2019
Outfall-2016-12	Outfall-2008 to 2018	Control 1-2008 to 2019
Outfall-2016-13	Outfall-2008 to 2018	Control 1-2008 to 2019
Outfall-2016-14	Outfall-2008 to 2018	Control 1-2008 to 2019
Outfall-2017-1	Outfall-2008 to 2018	Control 1-2008 to 2019
Outfall-2017-2	Outfall-2008 to 2018	Control 1-2008 to 2019
Outfall-2017-3	Outfall-2008 to 2018	Control 1-2008 to 2019
Outfall-2017-4	Outfall-2008 to 2018	Control 1-2008 to 2019
Outfall-2017-5	Outfall-2008 to 2018	Control 1-2008 to 2019
Outfall-2017-6	Outfall-2008 to 2018	Control 1-2008 to 2019
Outfall-2017-8	Outfall-2008 to 2018	Control 1-2008 to 2019
Outfall-2017-9	Outfall-2008 to 2018	Control 1-2008 to 2019
Outfall-2017-10	Outfall-2008 to 2018	Control 1-2008 to 2019
Outfall-2017-11	Outfall-2008 to 2018	Control 1-2008 to 2019
Outfall-2017-12	Outfall-2008 to 2018	Control 1-2008 to 2019
Outfall-2017-14	Outfall-2008 to 2018	Control 1-2008 to 2019

PERMUTATION TEST

trace statistic = $\text{tr}(\mathbf{Q}_m' \mathbf{H} \mathbf{Q}_m)$

first squared canonical correlation = (δ_1^2)

$\text{tr}(\mathbf{Q}_m' \mathbf{H} \mathbf{Q}_m)$: 0.72222 P: 0.0001

δ_1^2 : 0.65974 P: 0.0001

No. of permutations used: 9999

NEW SAMPLES

Canonical coordinate scores for New Samples

Sample	CAP1	CAP2
Outfall-2019-1	-0.0047	-0.0049
Outfall-2019-2	0.0379	-0.0053
Outfall-2019-3	0.0403	-0.009
Outfall-2019-4	0.0088	0.0005
Outfall-2019-5	0.0111	-0.0095
Outfall-2019-6	-0.0105	0.0009
Outfall-2019-7	-0.0195	-0.0086
Outfall-2019-8	0.0283	0.0005
Outfall-2019-9	0.0353	-0.0068
Outfall-2019-10	0.0238	-0.0059
Outfall-2019-11	0.046	-0.0034
Outfall-2019-12	0.0126	-0.0073
Outfall-2019-13	0.0366	0.0047
Outfall-2019-14	0.0402	0.0046

New sample classification

Sample	Group
Outfall-2019-1	Control 1-2008 to 2019
Outfall-2019-2	Outfall-2008 to 2018
Outfall-2019-3	Outfall-2008 to 2018
Outfall-2019-4	Control 1-2008 to 2019
Outfall-2019-5	Control 1-2008 to 2019
Outfall-2019-6	Control 1-2008 to 2019
Outfall-2019-7	Control 2-2008 to 2019
Outfall-2019-8	Outfall-2008 to 2018
Outfall-2019-9	Outfall-2008 to 2018
Outfall-2019-10	Control 1-2008 to 2019
Outfall-2019-11	Outfall-2008 to 2018



Outfall-2019-12
Outfall-2019-13
Outfall-2019-14

Control 1-2008 to 2019
Outfall-2008 to 2018
Outfall-2008 to 2018





Appendix L : Intertidal communities of Sydney's estuaries

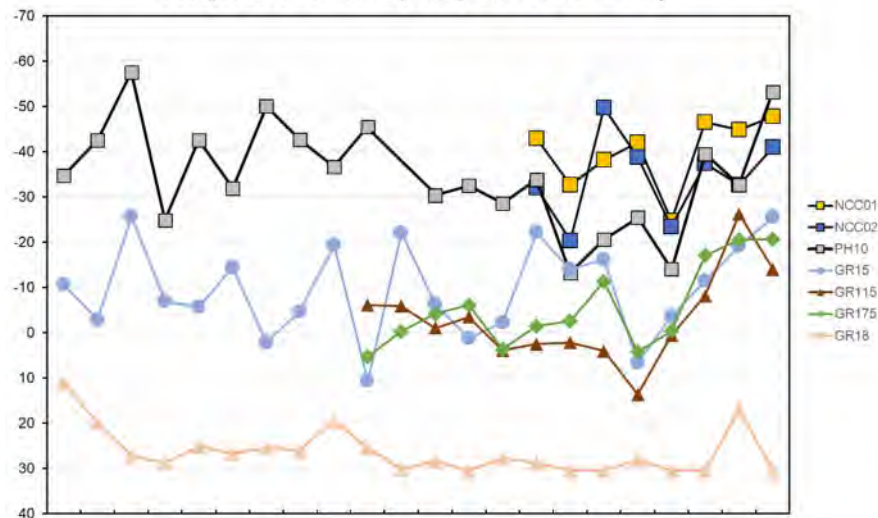
Intertidal rock platform communities

As a check of potential change in community structure of intertidal rock platforms at test sites, a comparison was made between control sites and other sites situated below urban catchments. This check was conducted under Principal Coordinates Analysis (PCO). PCO is an ordination technique that projects points onto axes that minimise the residual variation in the space of a chosen dissimilarity measure (Anderson et al. 2008). The user chooses the number of axes to be included in the output, but usually the first 2 or 3 axes contain most of the percent variation explained. In the analysis presented here, PCO was based on a Bray-Curtis distance measure matrix. The Bray-Curtis resemblance measure is focused on compositional changes in taxa identities (Anderson and Walsh 2013). The choice of this measure is considered appropriate as a change in taxonomic composition was recorded after remediation of the wastewater system (Sydney Water 2012). A separate analysis was conducted for each salinity zone.

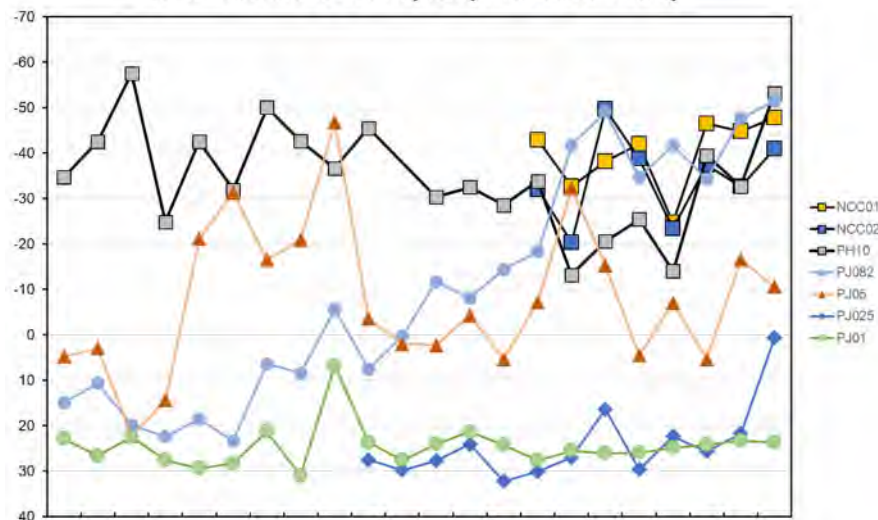
The PCO output allowed control chart style visualisation of centroids in Bray-Curtis space for each site by plotting output for PCO axis 1 against year. This explained about 65% of the variation for the low salinity zone and about 27% of the variation for the high salinity zone. This indicated the low salinity analysis described more variation in data of low salinity sites (86% of variation explained by the first two PCO axes) compared with that for the high salinity sites (47% of variation explained by the first two PCO axes) (Figure L-1 and Figure L-2) over the 1998 to 2019 period.

Test sites within higher salinity zones in 2019 were grouped near or within the range of variation recorded for higher salinity control sites. However, those in the lower salinity zone were well separated, particularly in the Parramatta River and Cooks River, from the recorded range of variation for the lower salinity control sites. In contrast, test sites within the Georges River (Como Woronora River GR15; Kyle Bay Georges River GR115; Edith Bay Georges River GR175), with the exception of Salt Pan Creek GR18, showed consistent improvement in the last three years and now sit within the range of control sites. This suggests the 2019 community structure in the lower salinity zone at most sites (Kissing Point Bay Parramatta River PJ025; Silverwater Bridge Parramatta River PJ01; Woolwich Baths Lane Cove River PJ05; Salt Pan Creek Georges River GR18; Alexandra Canal Cooks River CR04; Wolli Creek Cooks River CR06) were impaired. The exception being an improvement in the trend for the Hawthorn Canal arm within Iron Cove (PJ082).

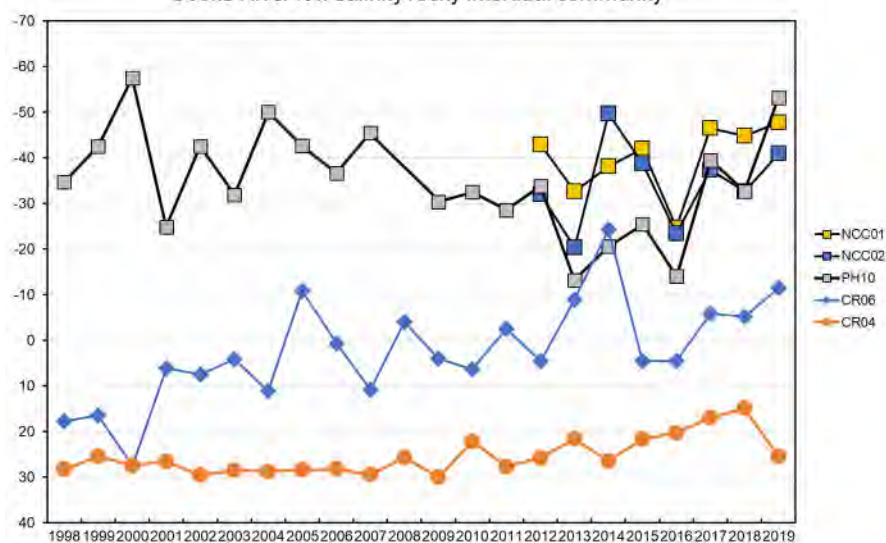
Georges River low salinity rocky intertidal community



Parramatta River low salinity rocky intertidal community

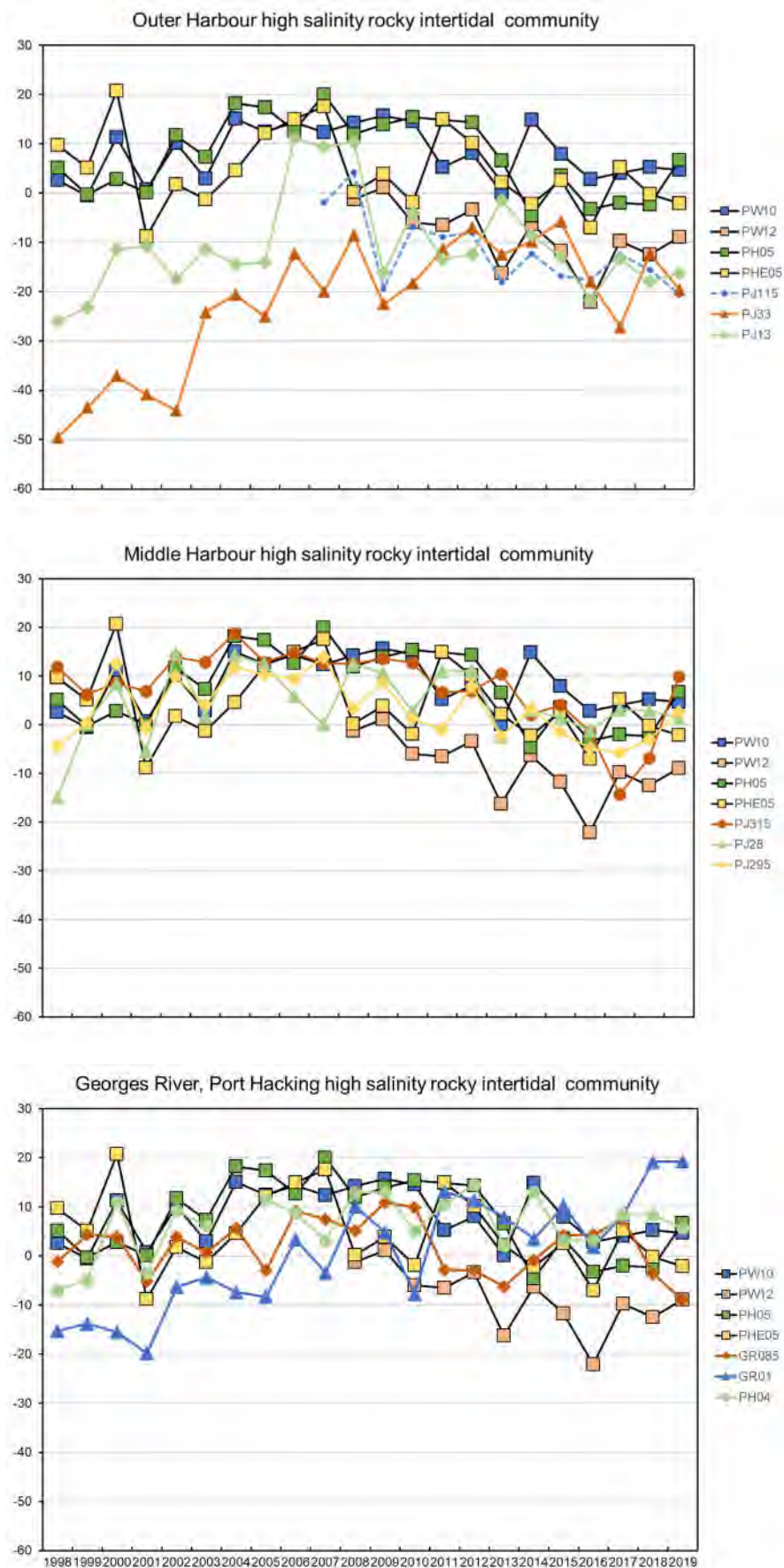


Cooks River low salinity rocky intertidal community



Black line colour represents control sites: other line colours represent test sites

Figure L-1 Relatively lower salinity zone with year plotted against Principal Coordinates Analysis axis 1 of distance among centroids for sites



Black line colour represents control sites: other line colours represent test sites

Figure L-2 Relatively higher salinity zone with year plotted against Principal Coordinates
Analysis axis 1 of distance among centroids for sites

Settlement panels

Settlement panels were used to supplement intertidal rock platform measurements and provide a focus on colonisation of intertidal larvae from the swimming juvenile life stages. Settlement panels were deployed at a number of sites that each included a large muddy intertidal area with mangroves. These areas of the estuaries did not have regular wave activity. The settlement panels consisted of weathered hardwood fence palings (weathered to remove tannins) that were vertically hammered into the mud at an intertidal height just below the lowest growing mangroves, and were left for four months to allow intertidal organisms to settle. After that time, they were removed and measured for the area covered by barnacles. Panels were deployed twice a year, during late spring and late autumn.

Barnacles were the dominant animal that settled and were a mixture of small types like *Elminius* and *Chamaesipho*, as well as some larger animals like *Balanus*. The relatively short deployment time of approximately four months, was inadequate for taxa such as snails (Mollusca) to develop to a sufficient size compared to barnacles that developed in a relatively shorter time where conditions were suitable for barnacle settlement. Previous analysis by Sydney Water (2012) showed reductions in barnacle cover (for example Rushcutters Bay PJ33) following sewer remediation suggesting higher levels of barnacle cover to be a possible indicator of wastewater overflows in wave-sheltered areas of the estuaries around Sydney.

In wave exposed areas of the coast and outer estuaries where there is regular wave occurrence, barnacles naturally grow on hard substrates and are not an indicator of the presence of wastewater. An estimate of barnacle cover was formed by multiplying the average size of barnacles with measured abundance.

Analysis of variance (ANOVA) indicated significant differences between sites situated in relatively higher salinity waters of the outer estuaries of Sydney ($df = 9$, $MS = 684.410$, $F = 16.73$, $p < 0.0001$). A multiple mean (SNK) comparison indicated two sites on the Georges River being significantly different from each other and the remaining overlapping group of sites Figure L-3.

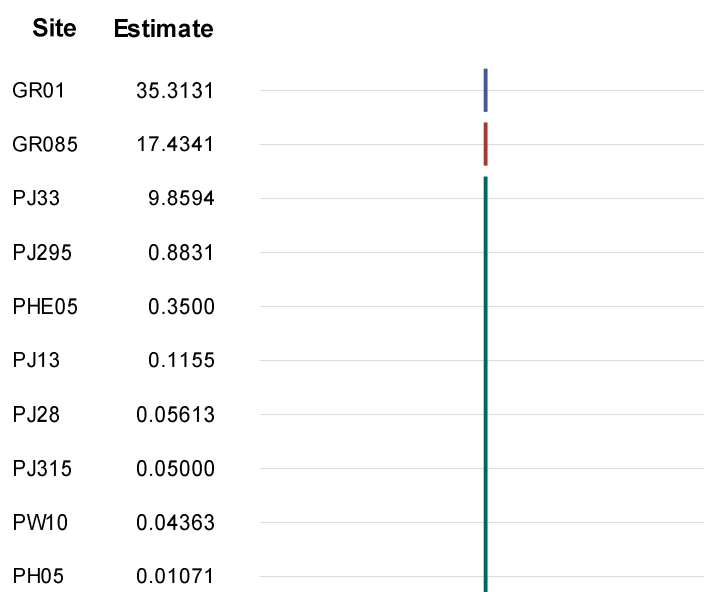


Figure L-3 Multiple mean comparison groupings of relatively high salinity locations for 2019-20.
(means covered by the same bar are not significantly different)

ANOVA indicated significant differences between sites situated in relatively lower salinity waters of the inner estuaries of Sydney (df = 12, MS = 3540.468, F = 22.51, p < 0.0001). A multiple mean (SNK) comparison test indicated one significantly different site on the Georges River from the remaining four overlapping groups of sites (Figure L-4).

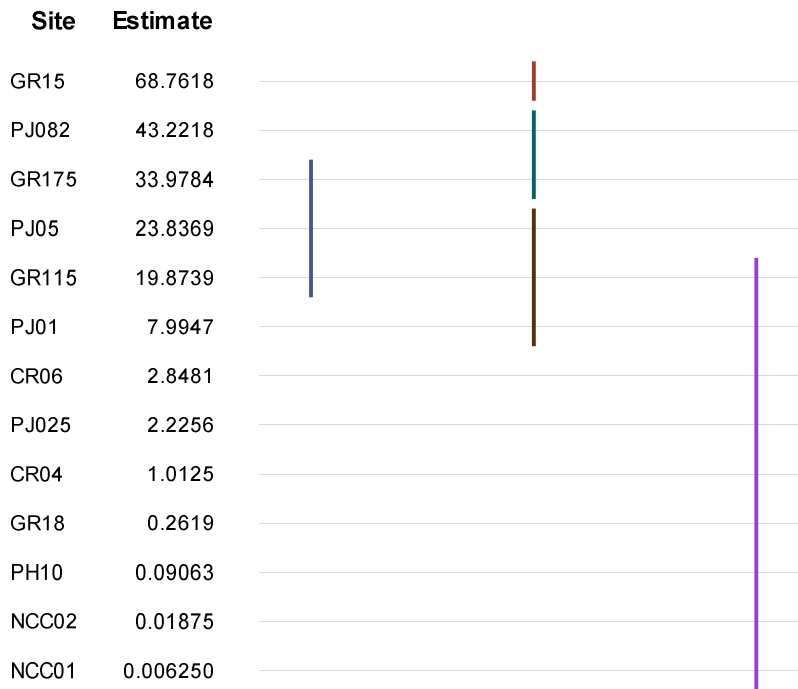


Figure L-4 Multiple mean comparison groupings of relatively lower salinity locations for 2019-20. (means covered by the same bar are not significantly different)



Appendix M : Hawkesbury-Nepean

River water quality trends

The Hawkesbury-Nepean River sites are presented in the following order from upstream to downstream:

- N92: Nepean River at Maldon Weir
- N75: Nepean River at Sharpes Weir
- N67: Nepean River at Wallacia Bridge
- N57: Nepean River at Penrith Weir
- N51: Nepean River opposite Fitzgerald Creek
- N48A: Nepean River at Smith Road
- N44: Nepean River at Yarramundi Bridge
- N42: Hawkesbury River at North Richmond
- N39: Hawkesbury River at Freemans Reach
- NS04A: Lower South Creek at Fitzroy Bridge
- N35: Hawkesbury River at Wilberforce
- NC11A: Lower Cattai Creek at Cattai Ridge Road
- N3001: Hawkesbury River off Cattai SRA
- N26: Hawkesbury River at Sackville Ferry
- N2202: Lower Colo River at Putty Road
- N18: Hawkesbury River at Leets Vale
- NB13: Berowra Creek at Calabash Bay
- NB11: Berowra Creek off Square Bay

The water quality plots are presented in the following groups and order of analytes:

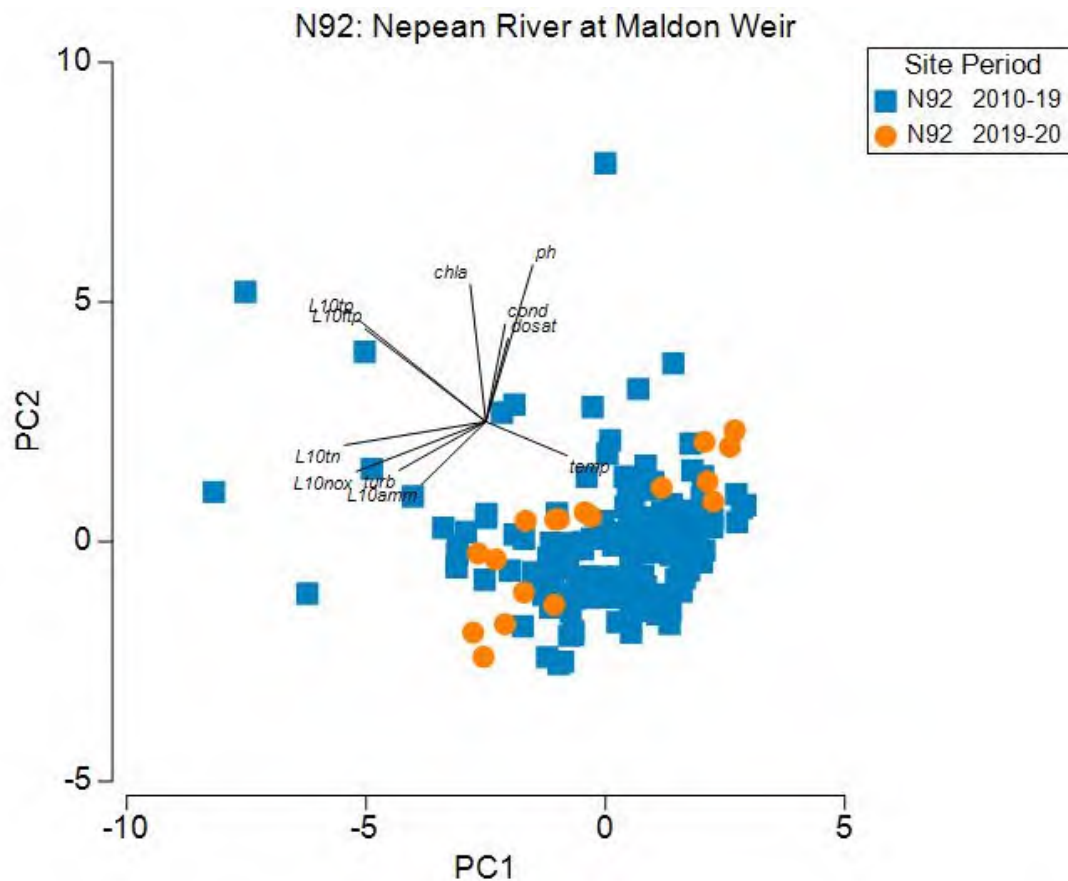
Nutrients, chlorophyll-a and algae

- Ammonia nitrogen
- Oxidised nitrogen
- Total nitrogen
- Filterable total phosphorus
- Total phosphorus
- Chlorophyll-a
- Total algal biovolume
- Blue-green algal biovolume
- Toxic blue-green algal biovolume
- Toxic blue-green algal count

Other physico-chemical analytes

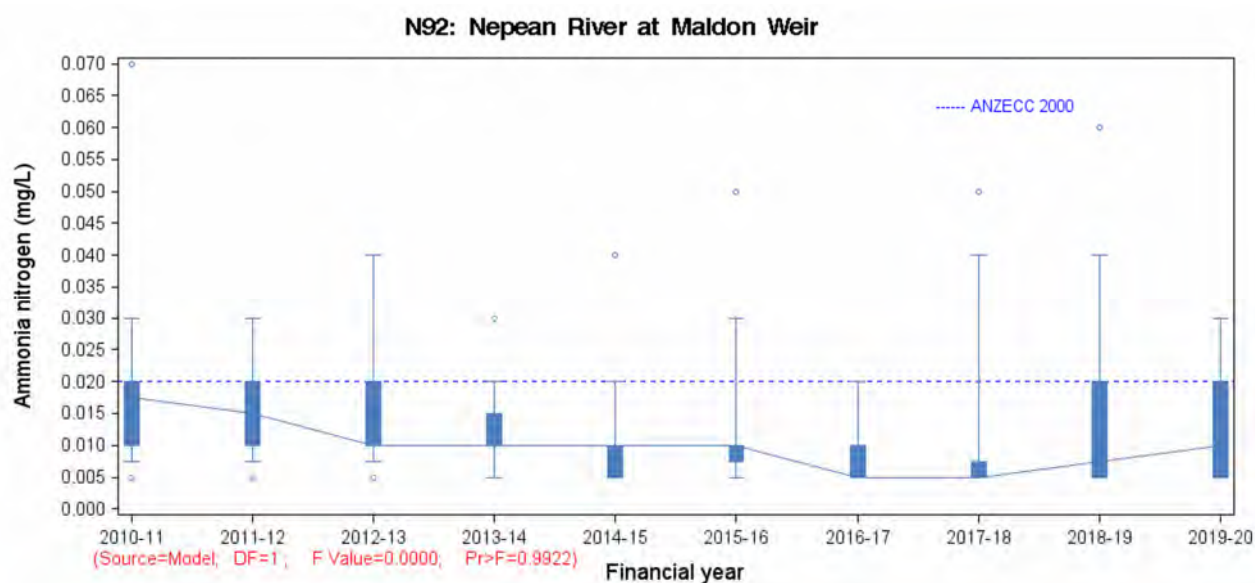
- Conductivity
- Dissolved oxygen (mg/L)
- Dissolved oxygen saturation (%)
- pH
- Temperature
- Turbidity

N92: Nepean River at Maldon Weir

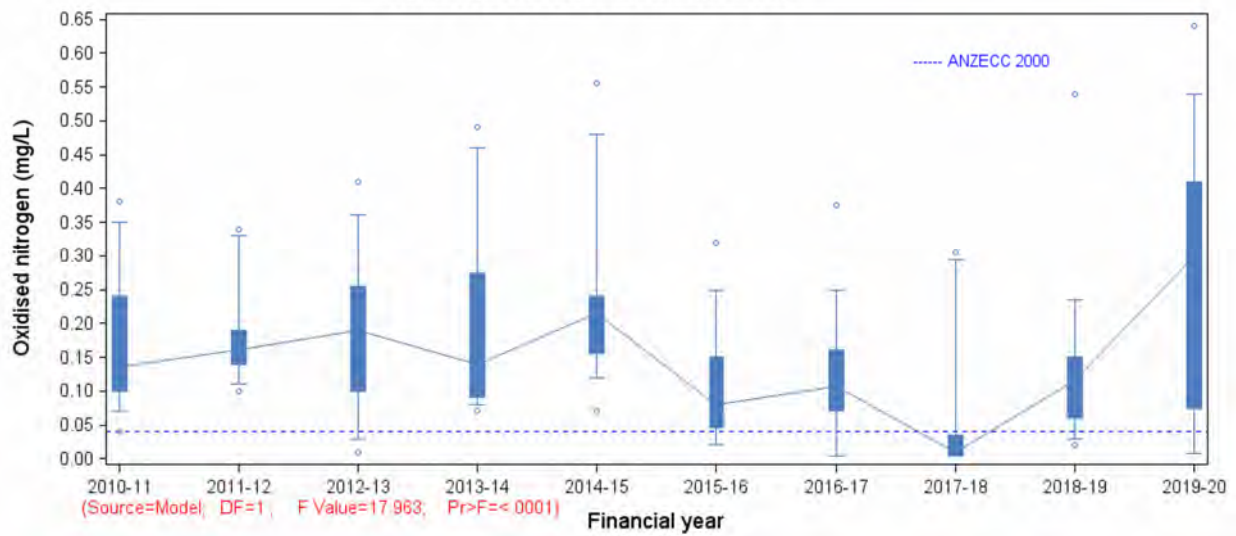


The ordination plot from Principal Components Analysis suggested water quality of the Nepean River at Maldon Weir in 2019-20 was similar in variability to that recorded in the period 2010 to 2019.

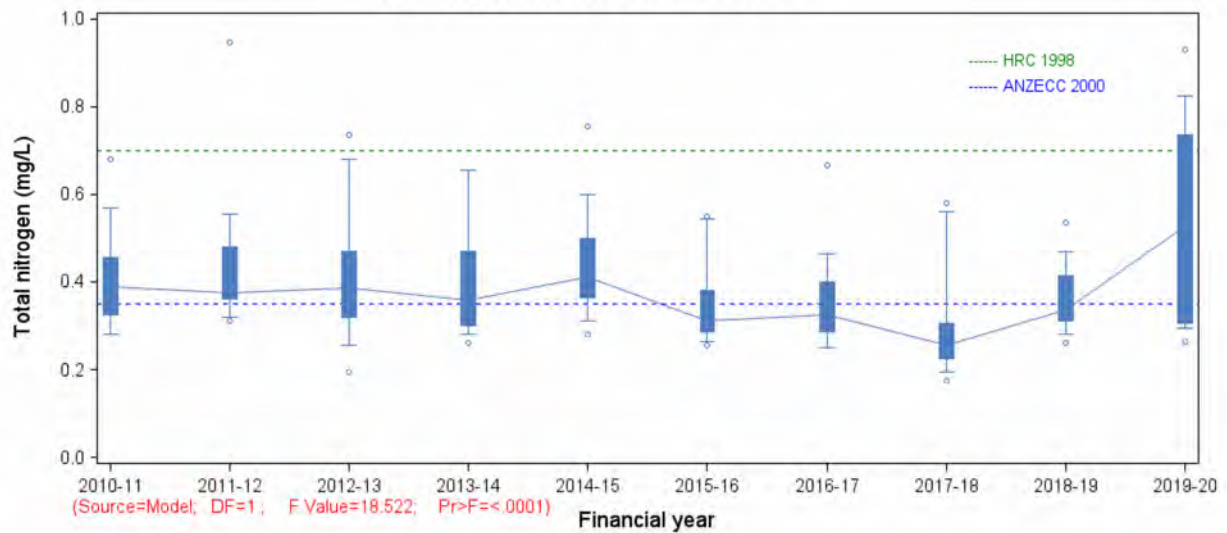
Nutrients, chlorophyll-a and algae



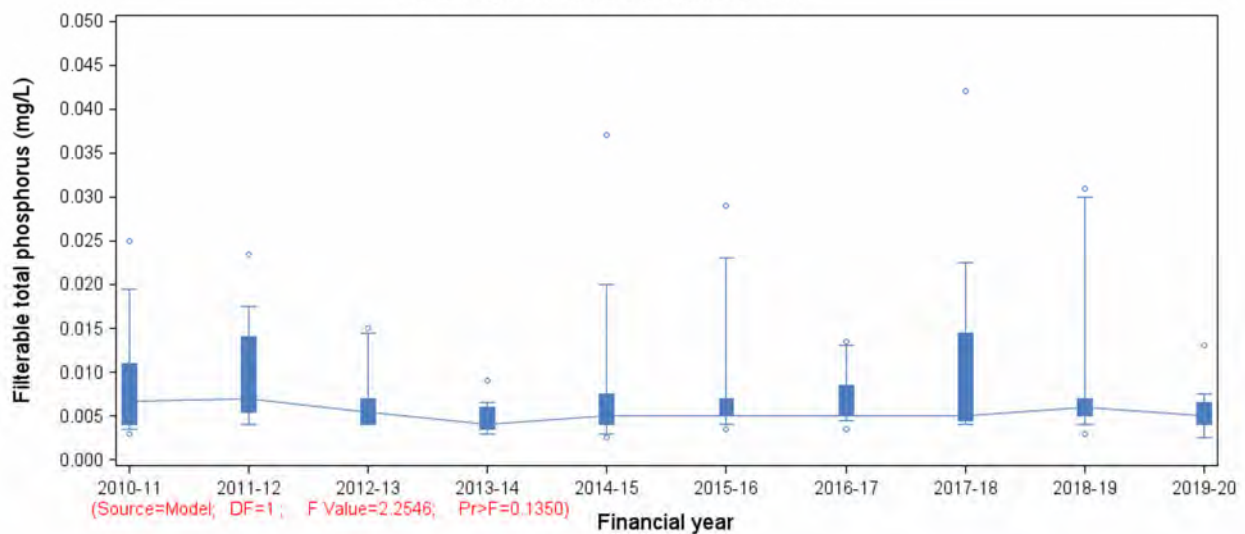
N92: Nepean River at Maldon Weir



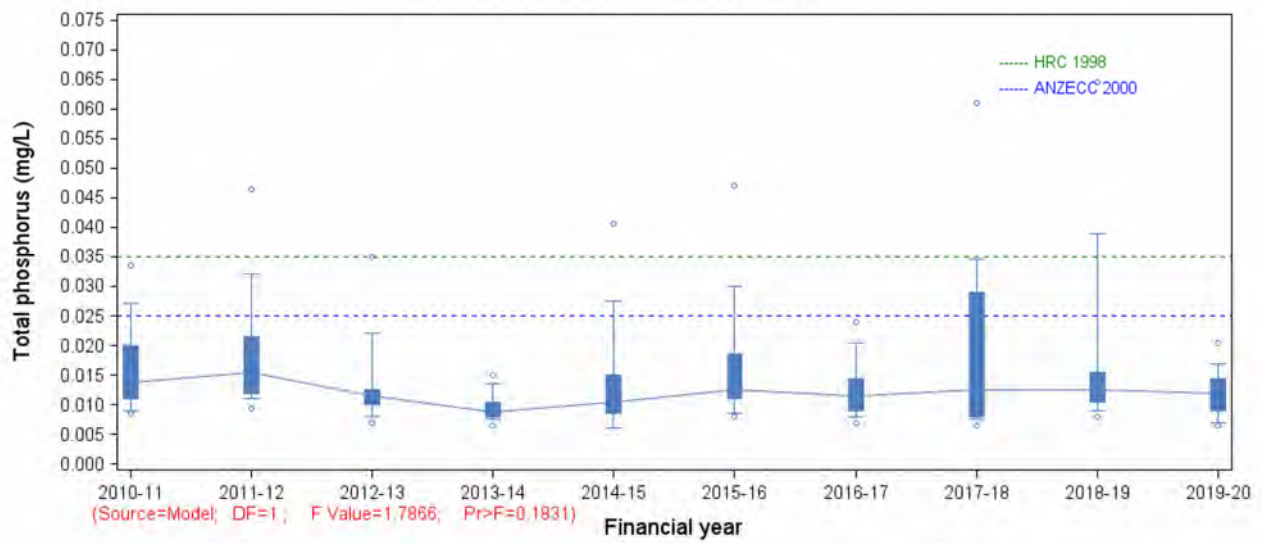
N92: Nepean River at Maldon Weir



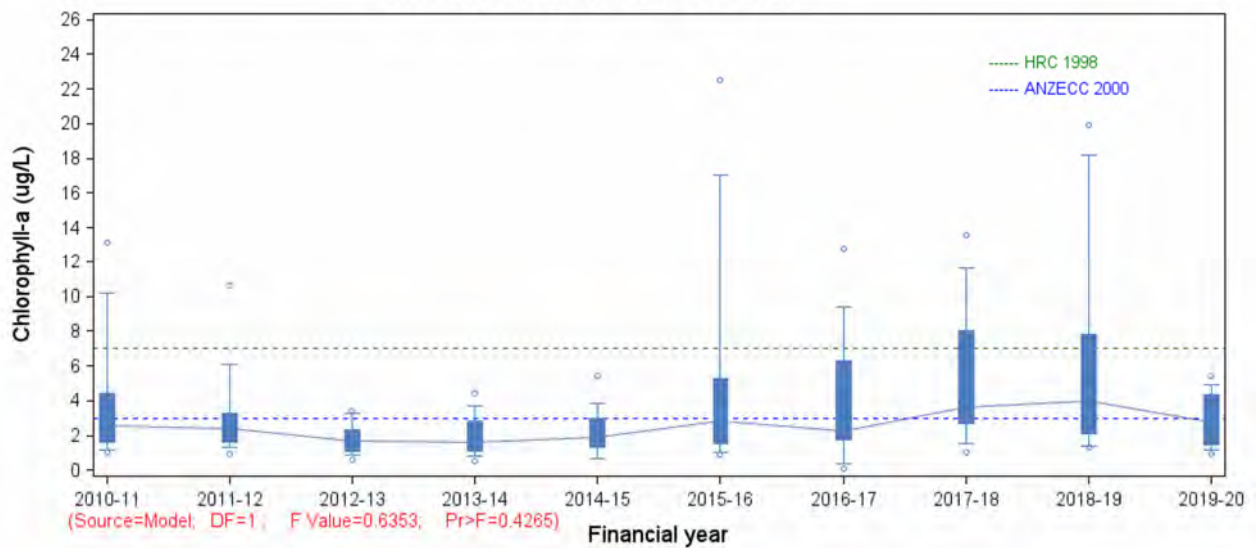
N92: Nepean River at Maldon Weir



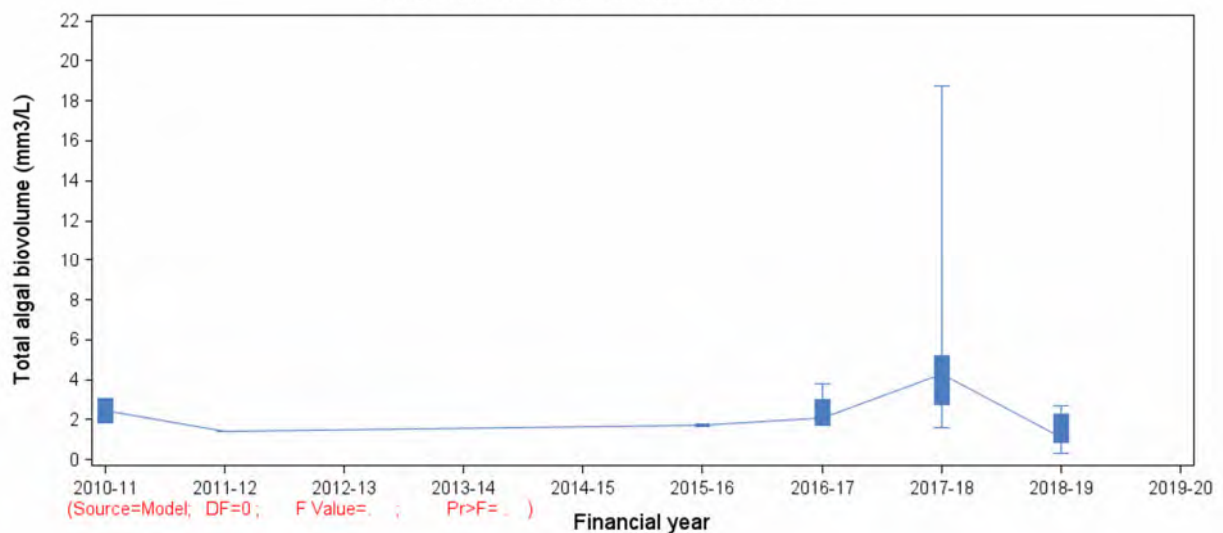
N92: Nepean River at Maldon Weir



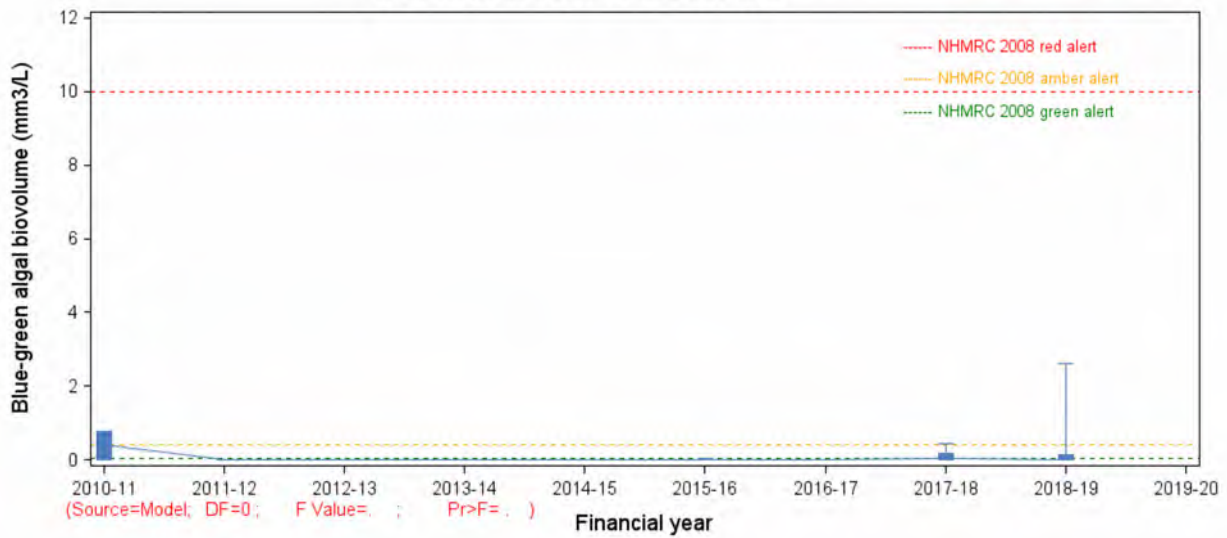
N92: Nepean River at Maldon Weir



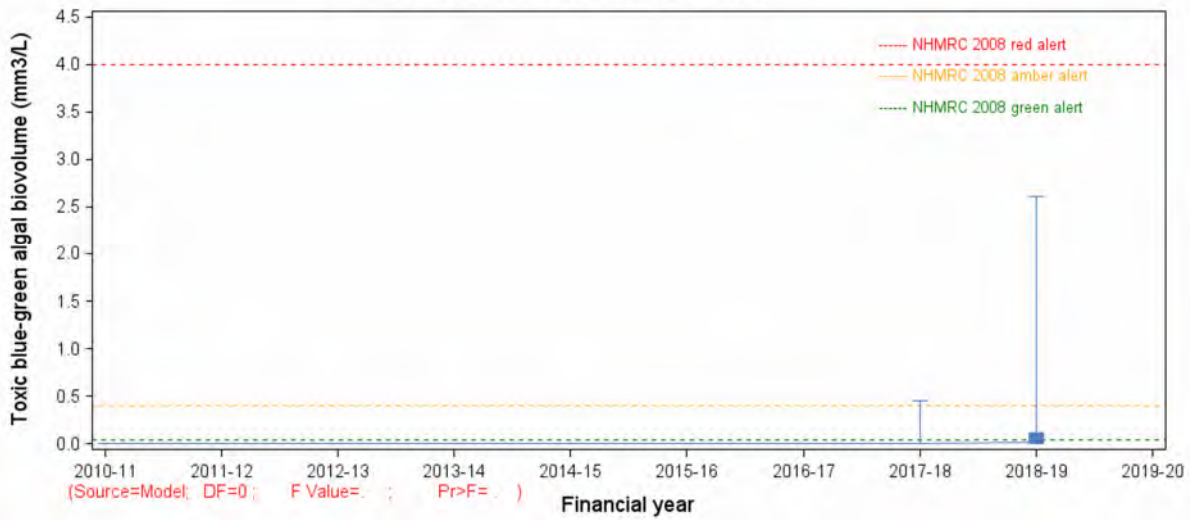
N92: Nepean River at Maldon Weir



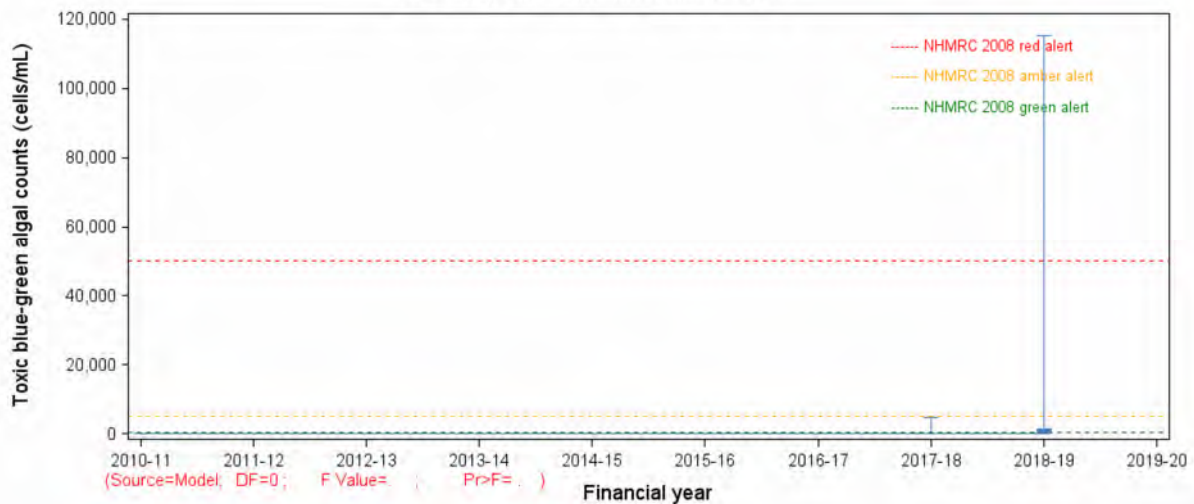
N92: Nepean River at Maldon Weir



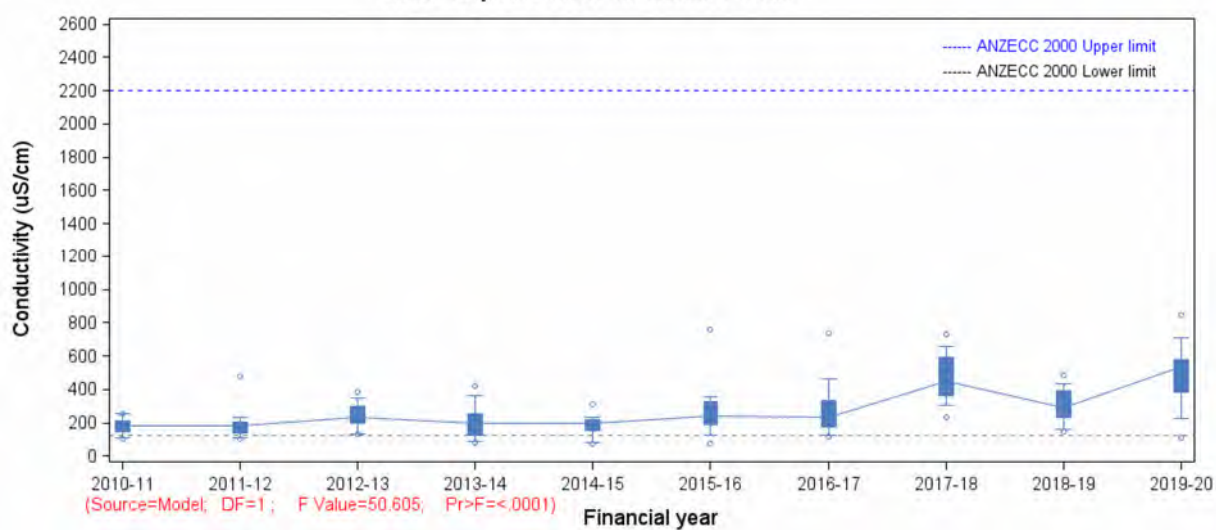
N92: Nepean River at Maldon Weir



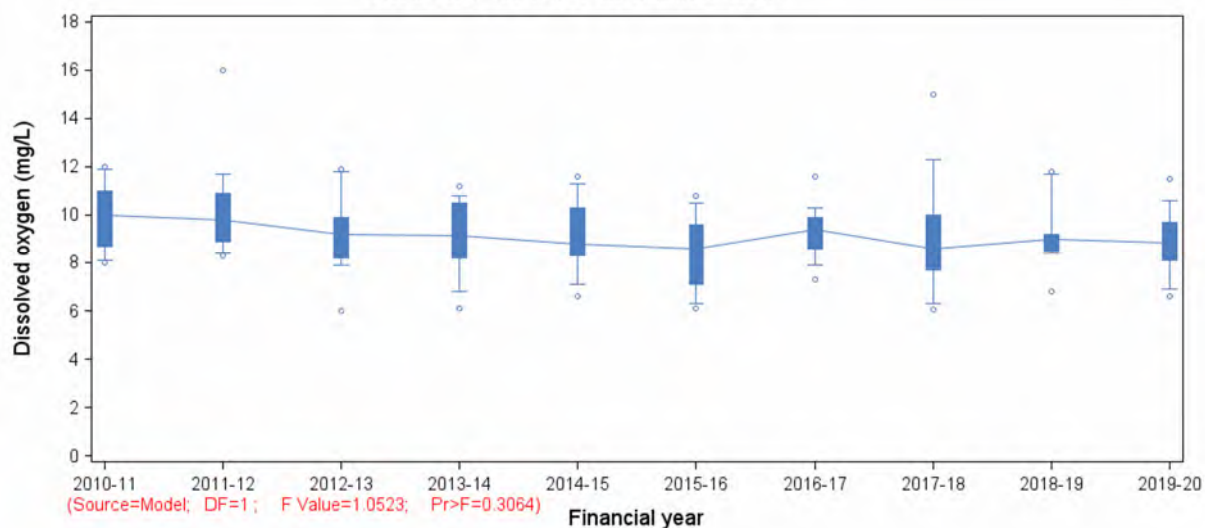
N92: Nepean River at Maldon Weir



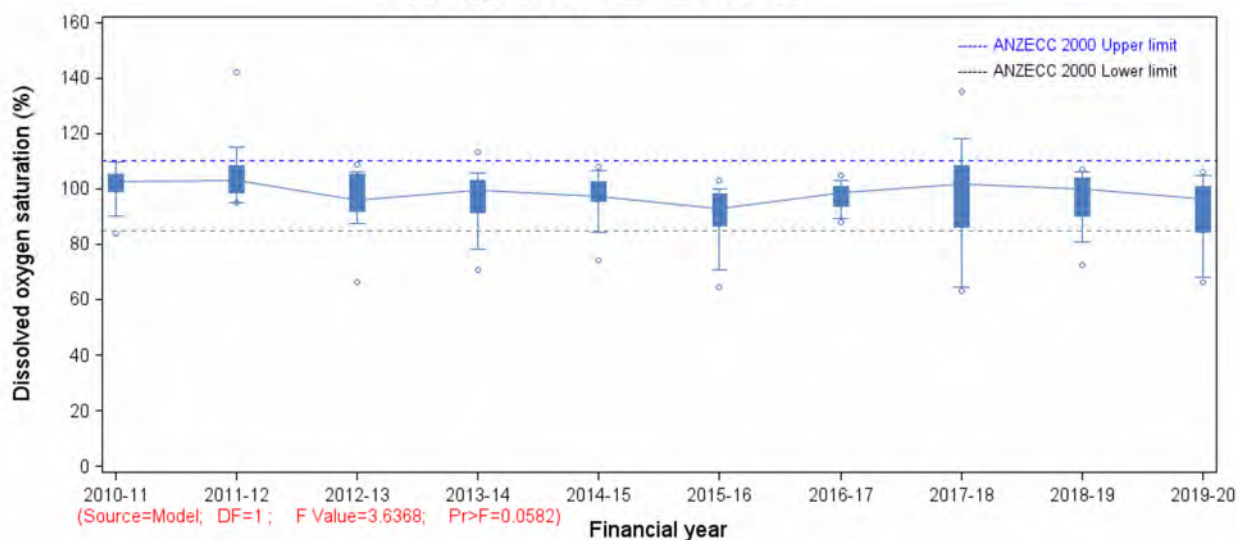
N92: Nepean River at Maldon Weir



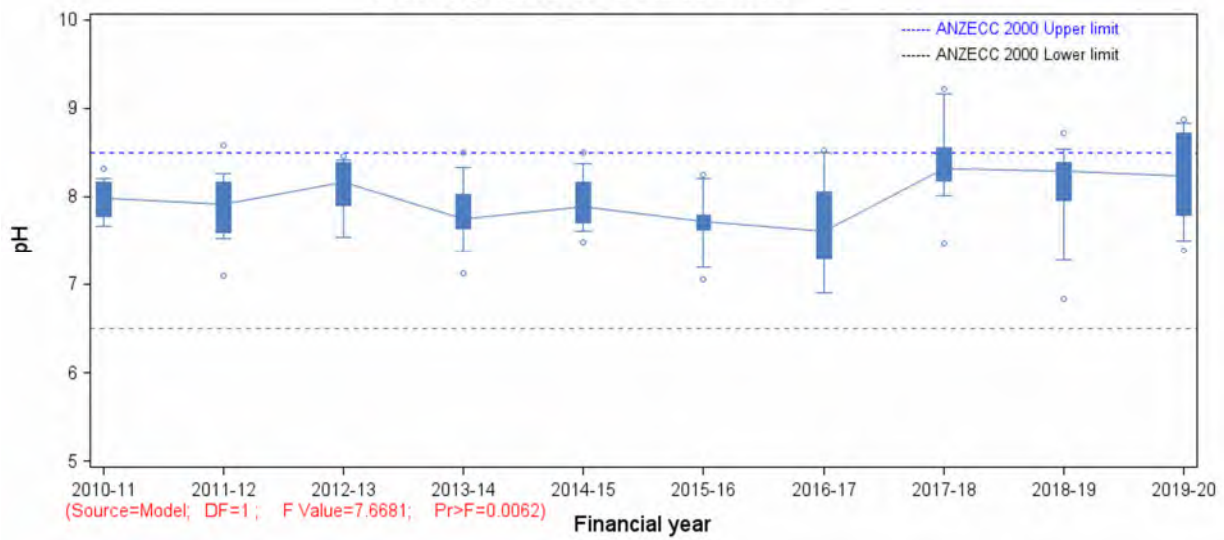
N92: Nepean River at Maldon Weir



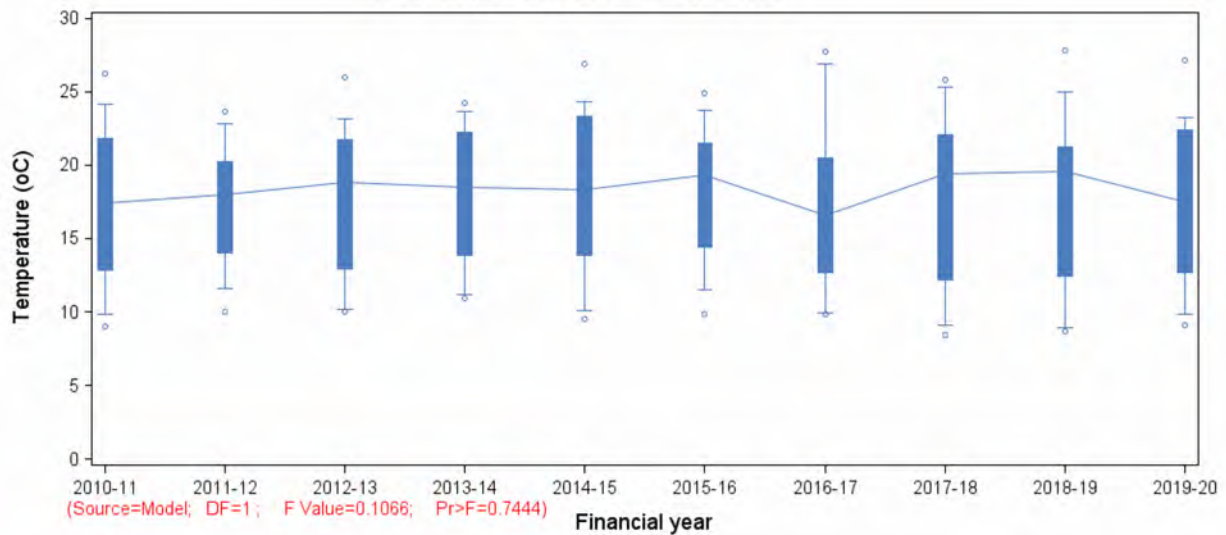
N92: Nepean River at Maldon Weir



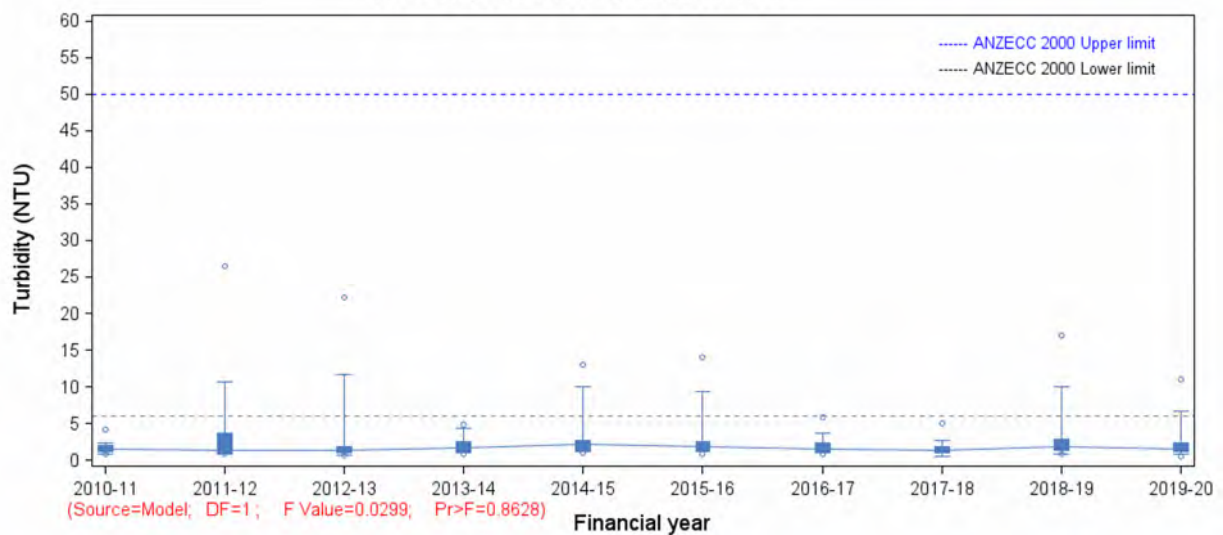
N92: Nepean River at Maldon Weir

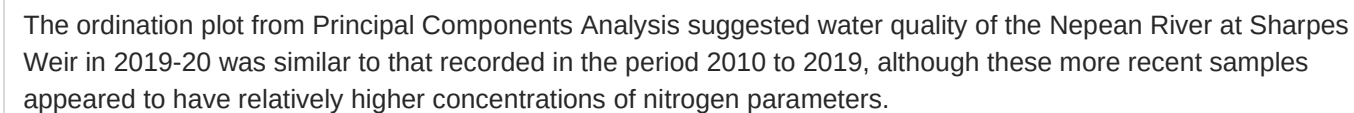


N92: Nepean River at Maldon Weir



N92: Nepean River at Maldon Weir

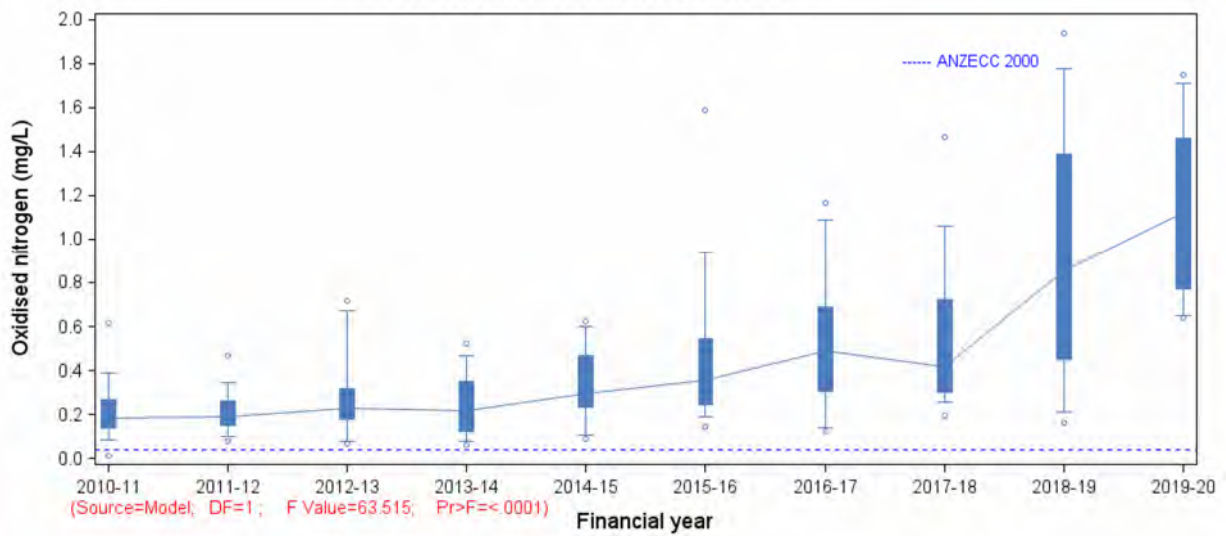




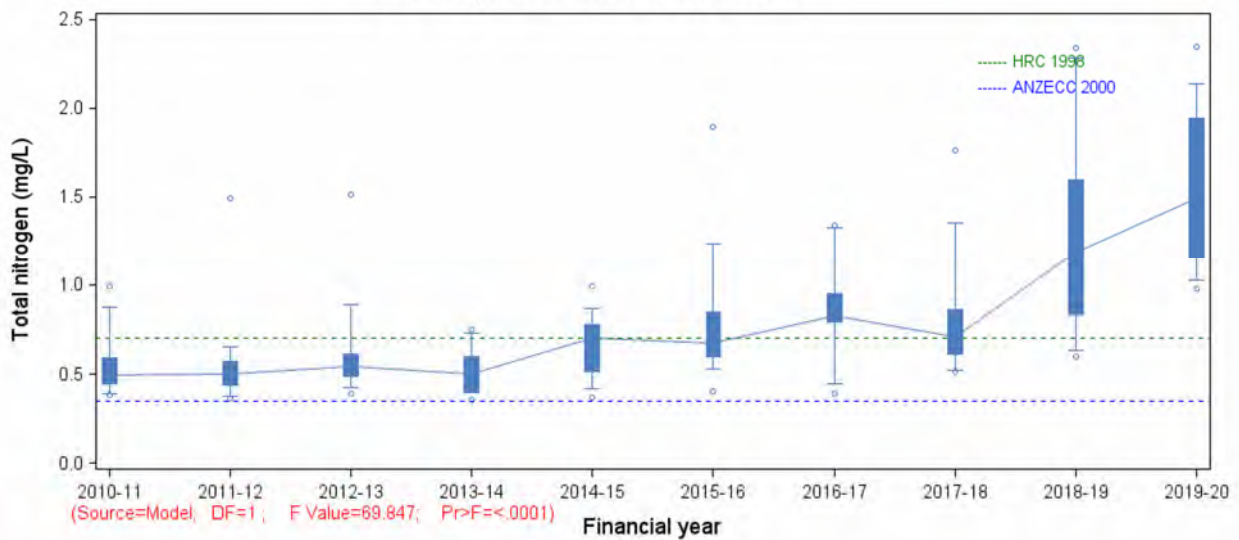
Nutrients, chlorophyll-a and algae



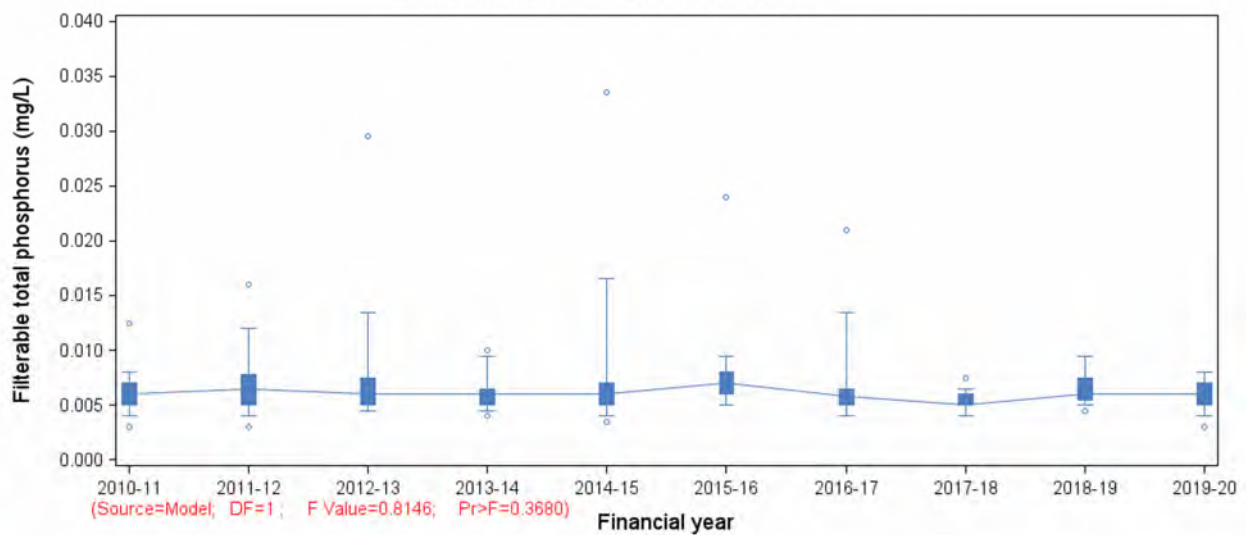
N75: Nepean River at Sharpes Weir



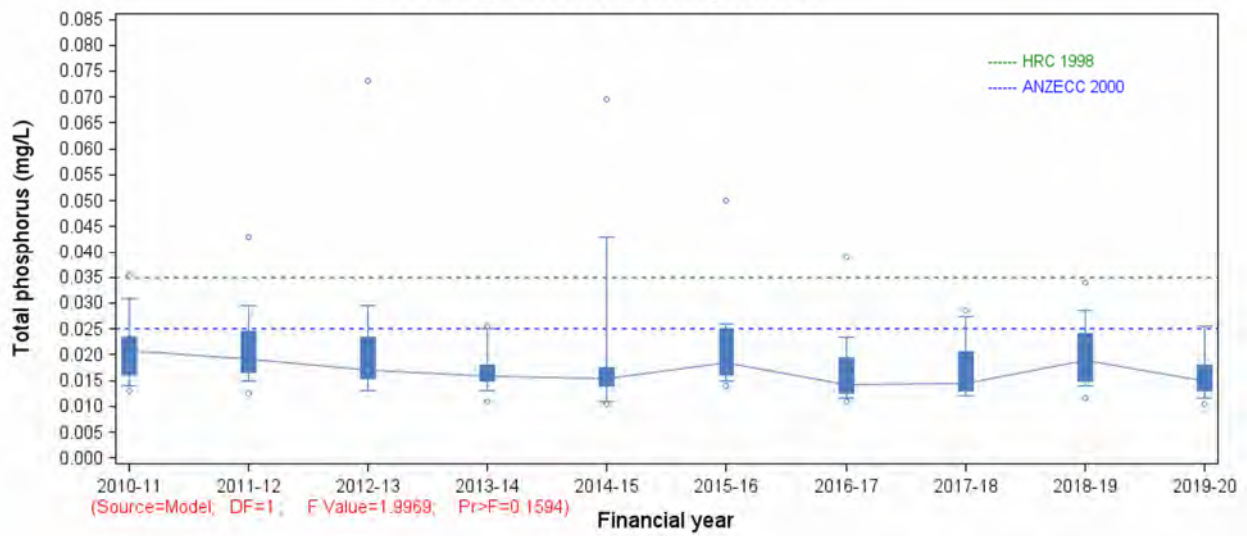
N75: Nepean River at Sharpes Weir



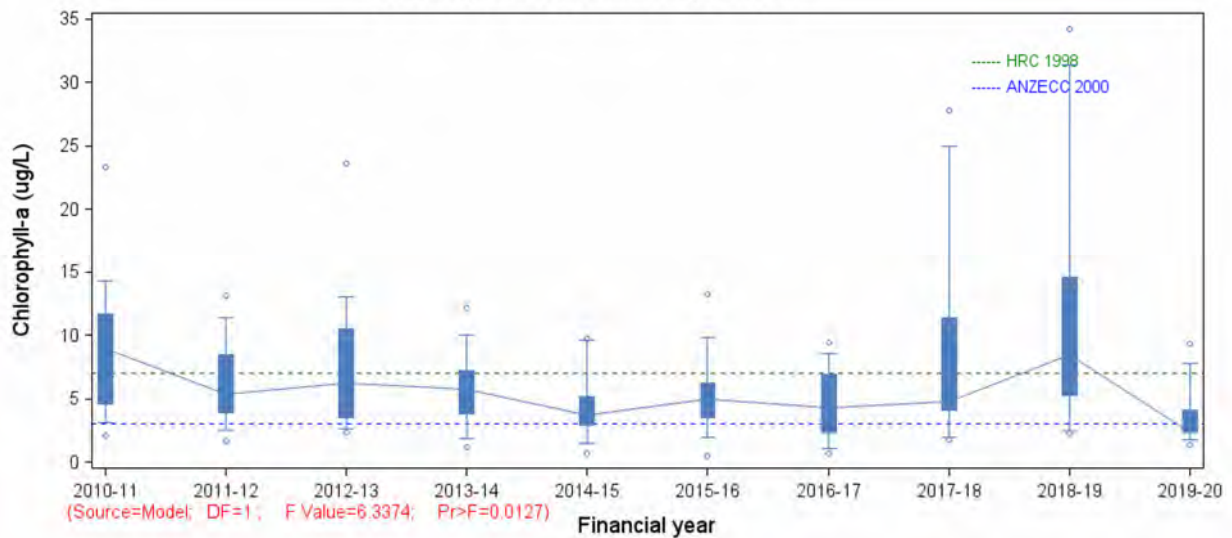
N75: Nepean River at Sharpes Weir



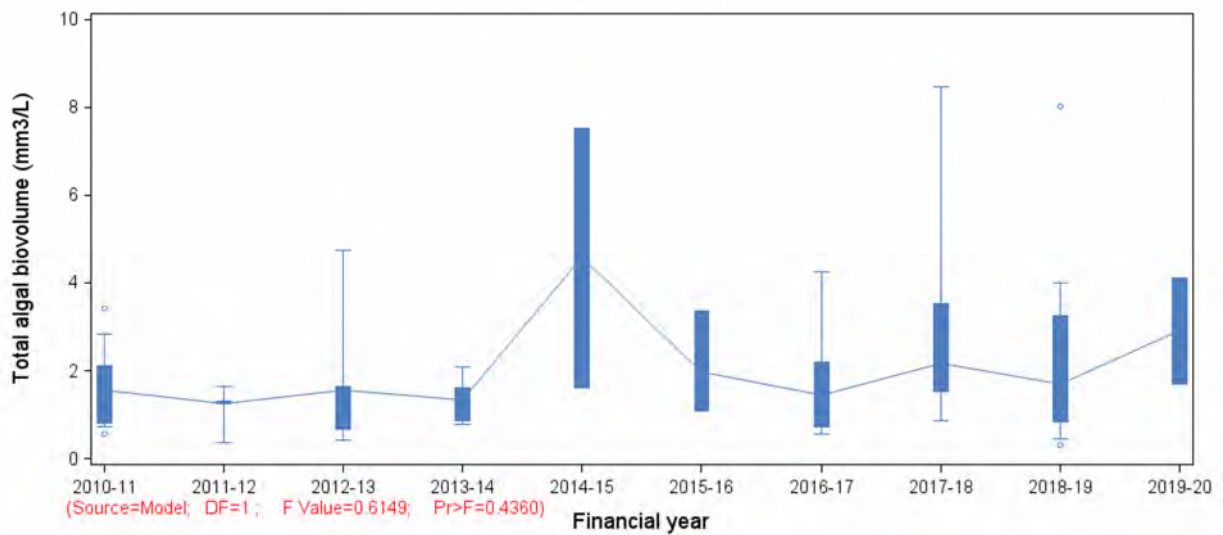
N75: Nepean River at Sharpes Weir



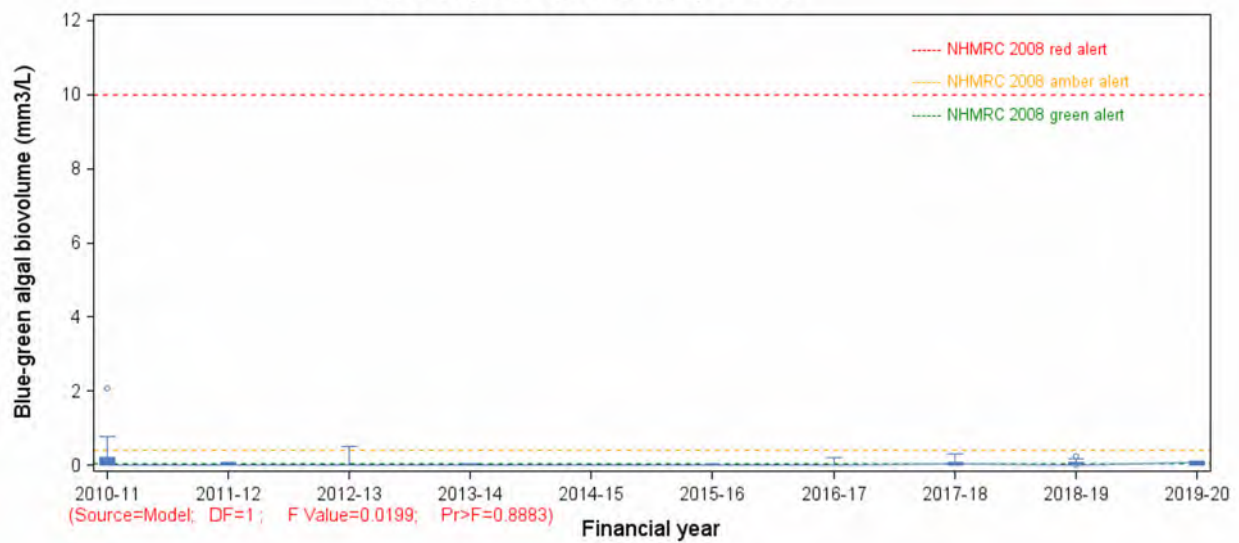
N75: Nepean River at Sharpes Weir



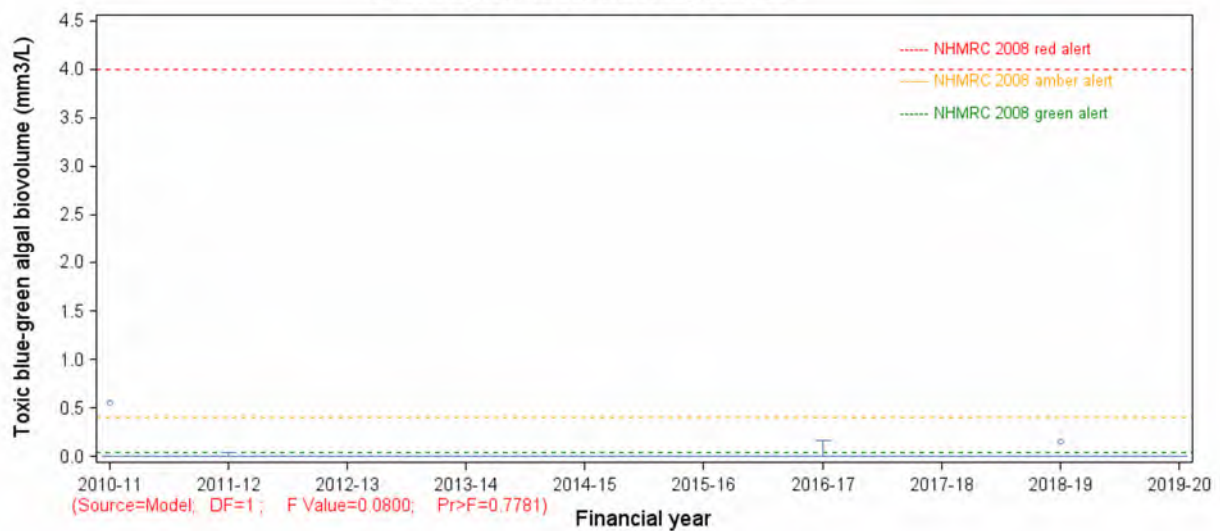
N75: Nepean River at Sharpes Weir



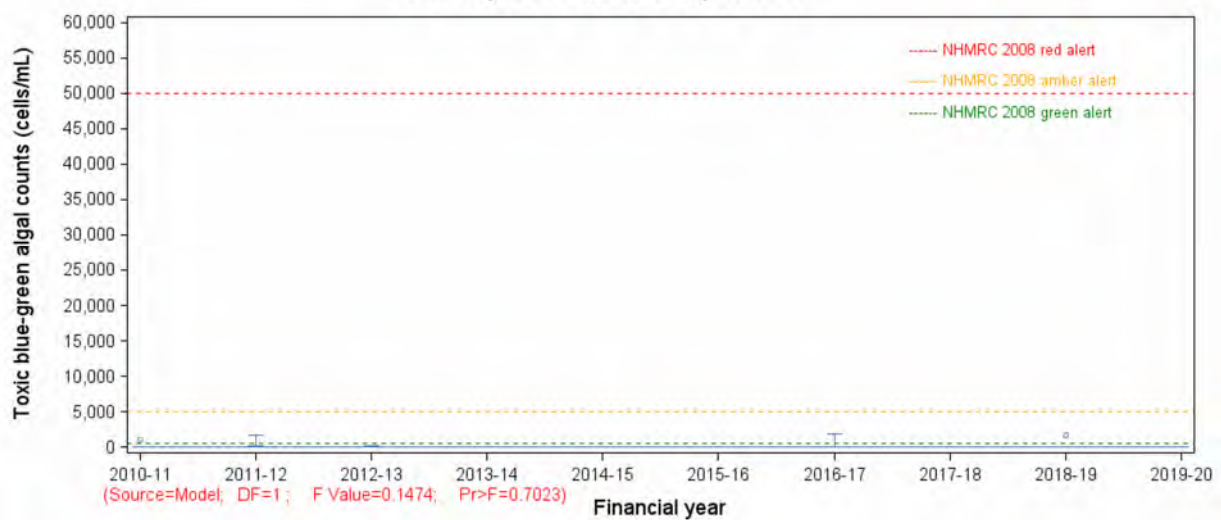
N75: Nepean River at Sharpes Weir

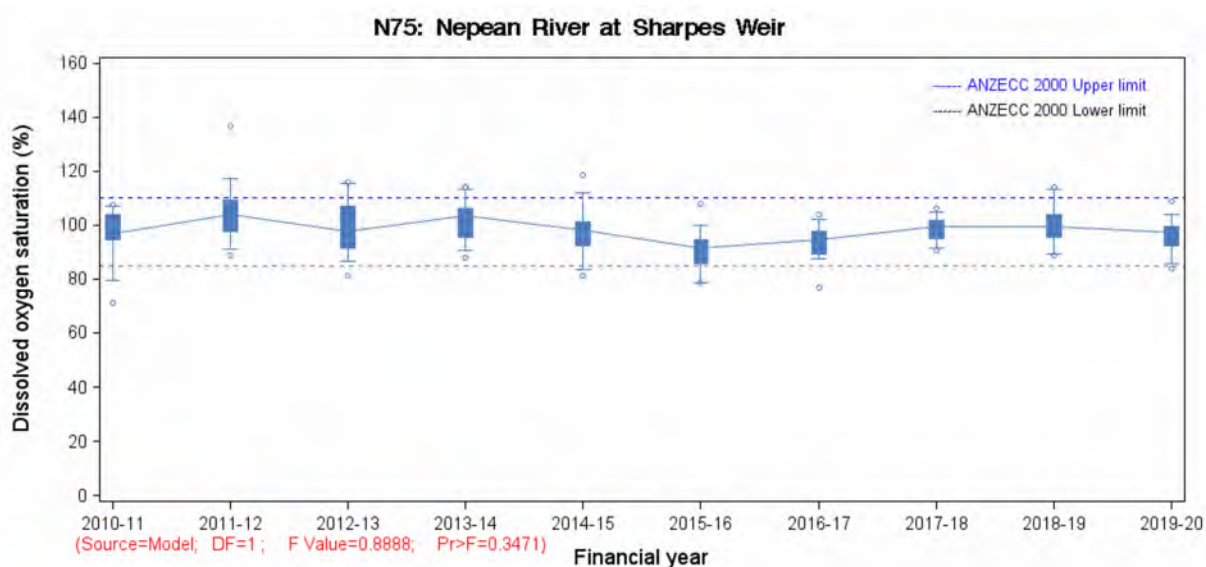
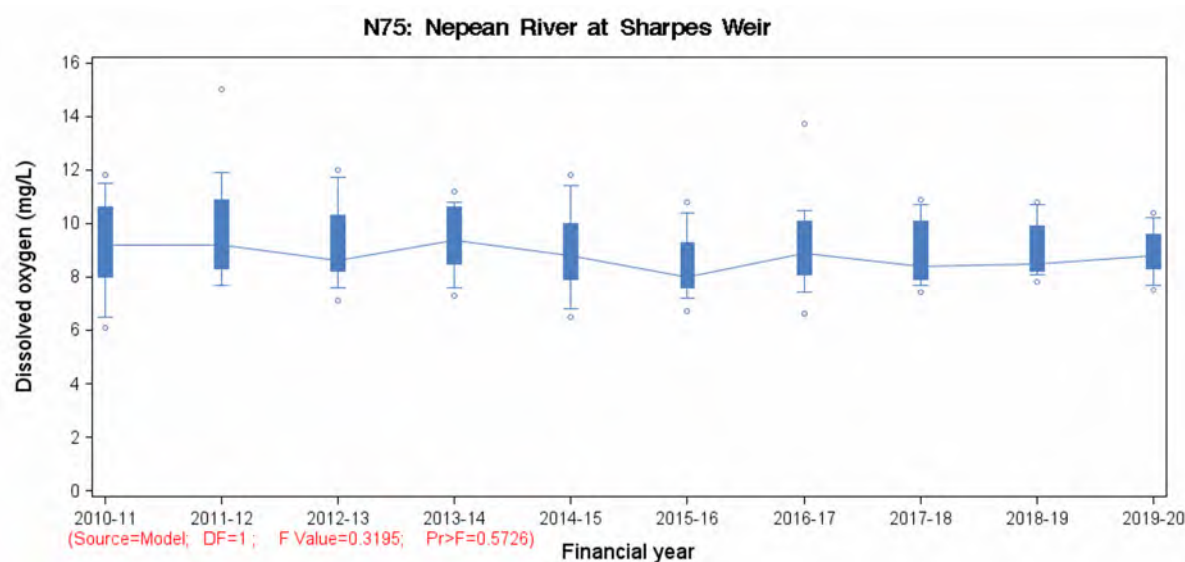
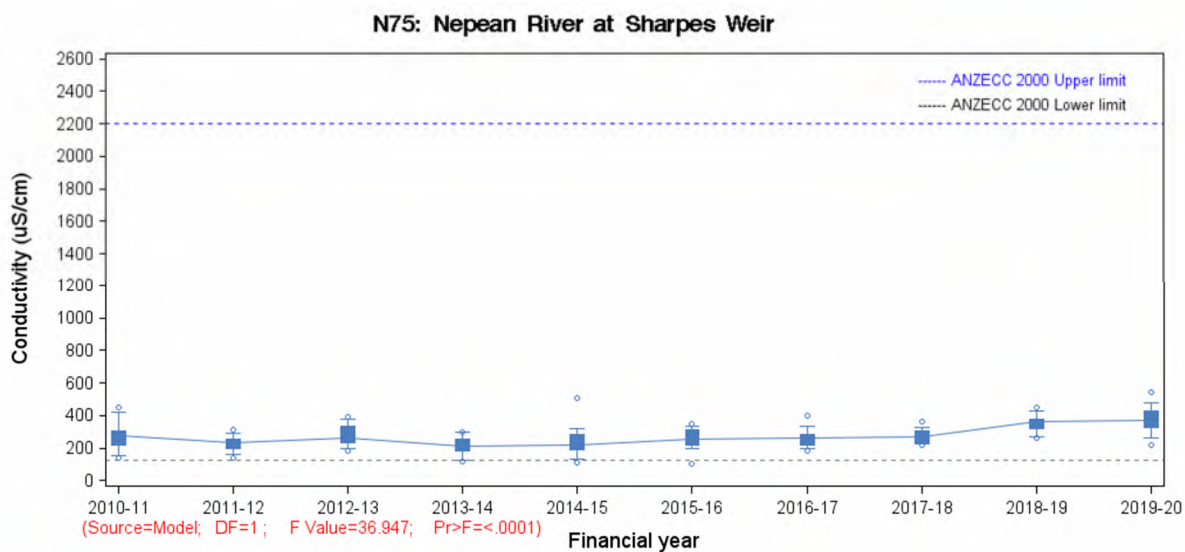


N75: Nepean River at Sharpes Weir

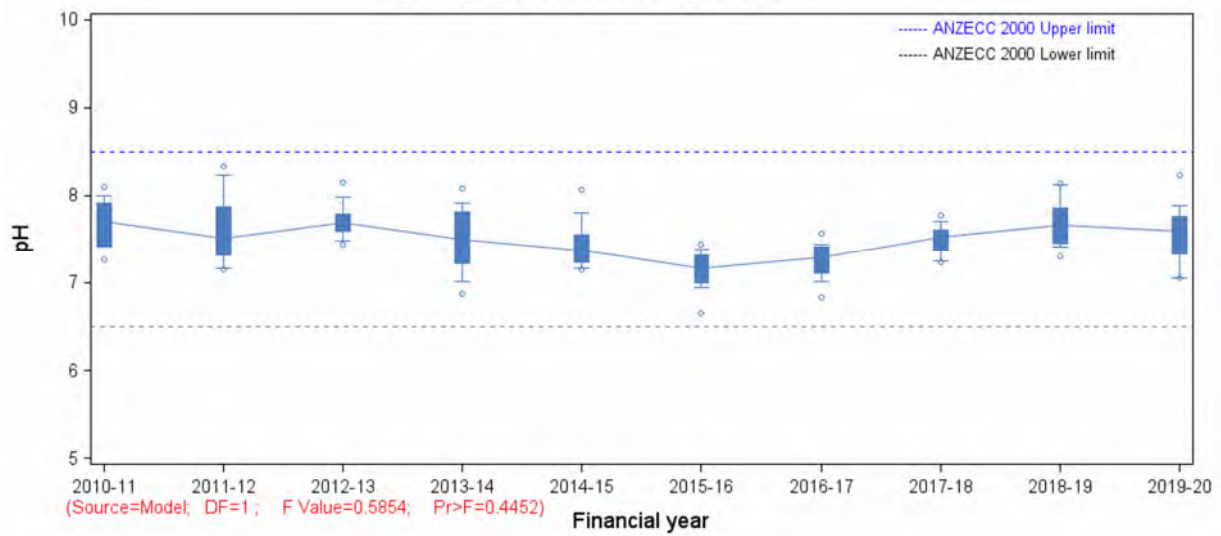


N75: Nepean River at Sharpes Weir

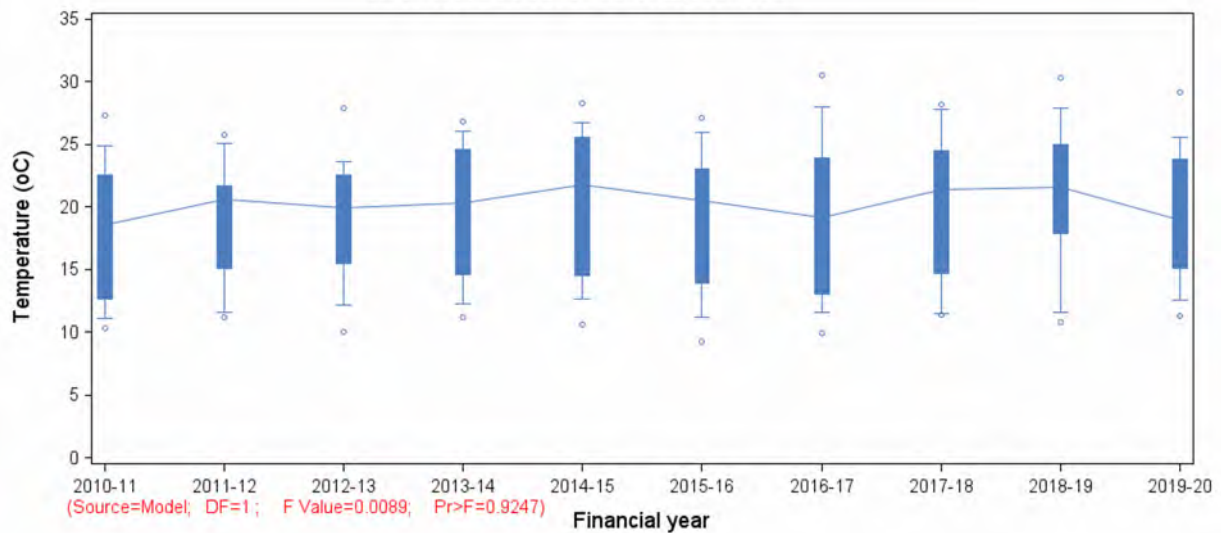




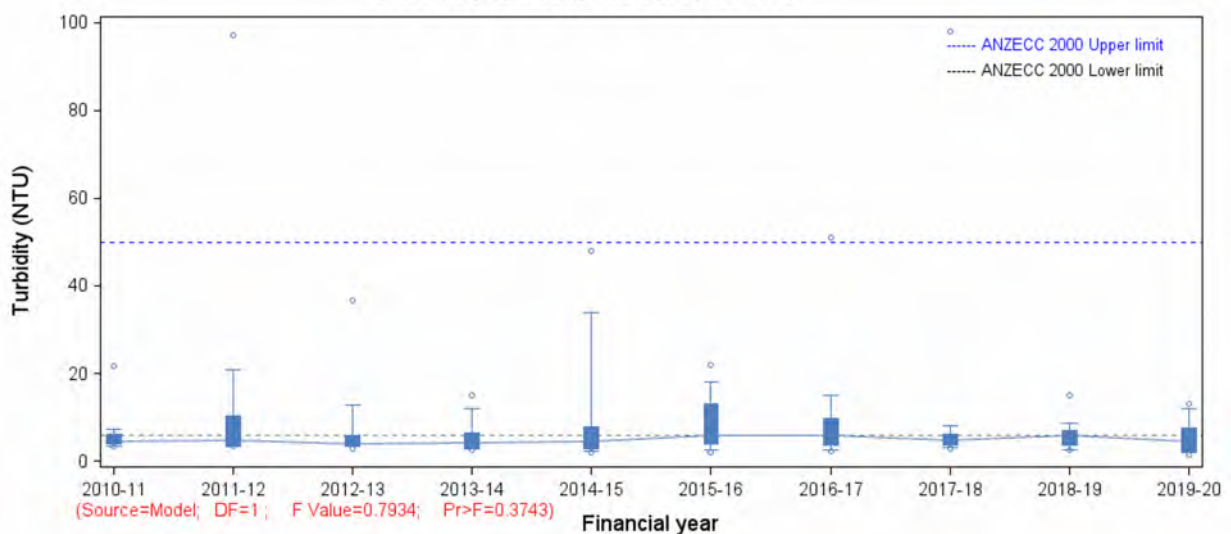
N75: Nepean River at Sharpes Weir



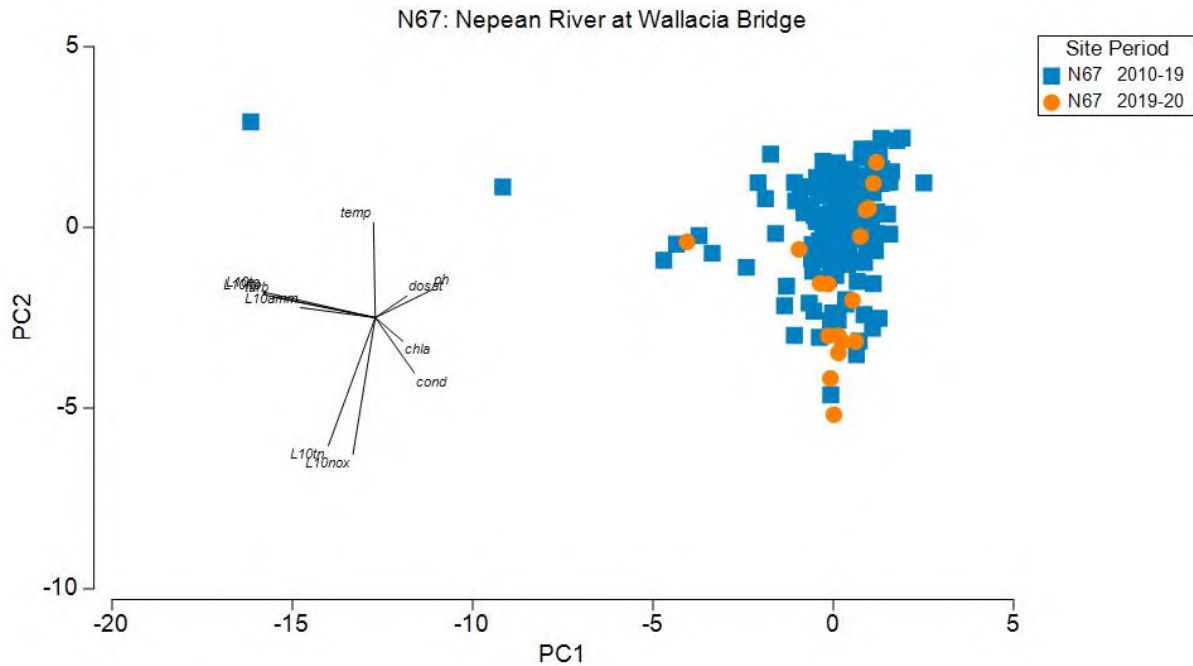
N75: Nepean River at Sharpes Weir



N75: Nepean River at Sharpes Weir

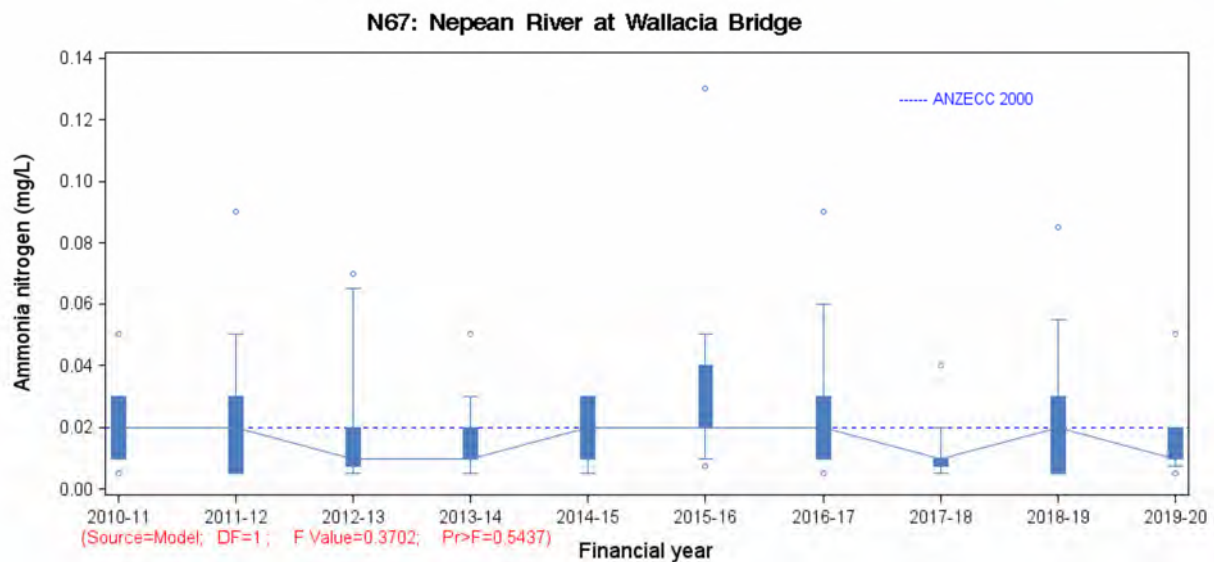


N67: Nepean River at Wallacia Bridge

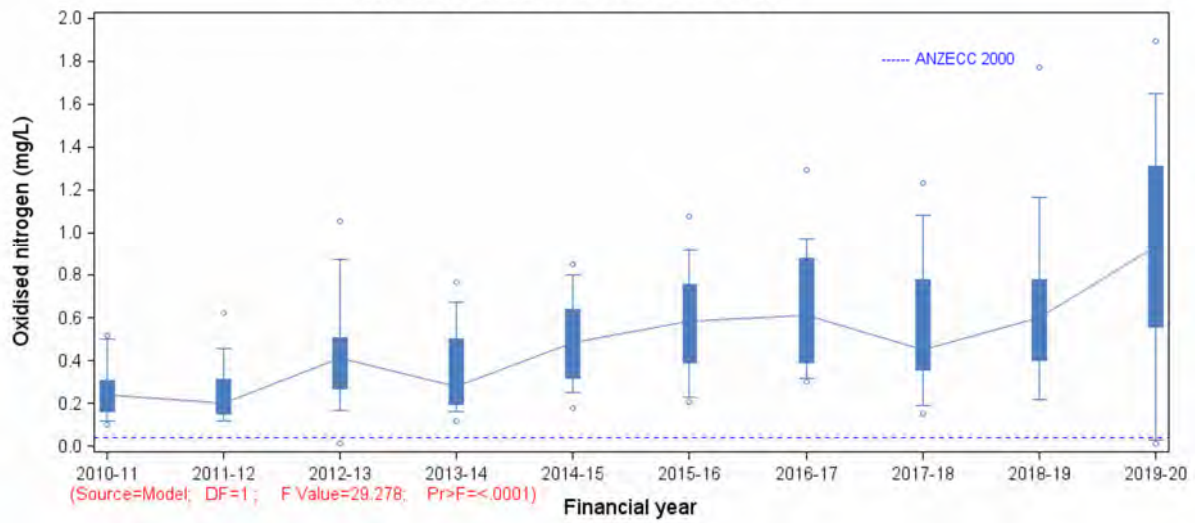


The ordination plot from Principal Components Analysis suggested water quality of the Nepean River at Wallacia Bridge in 2019-20 was similar to that recorded in the period 2010 to 2019.

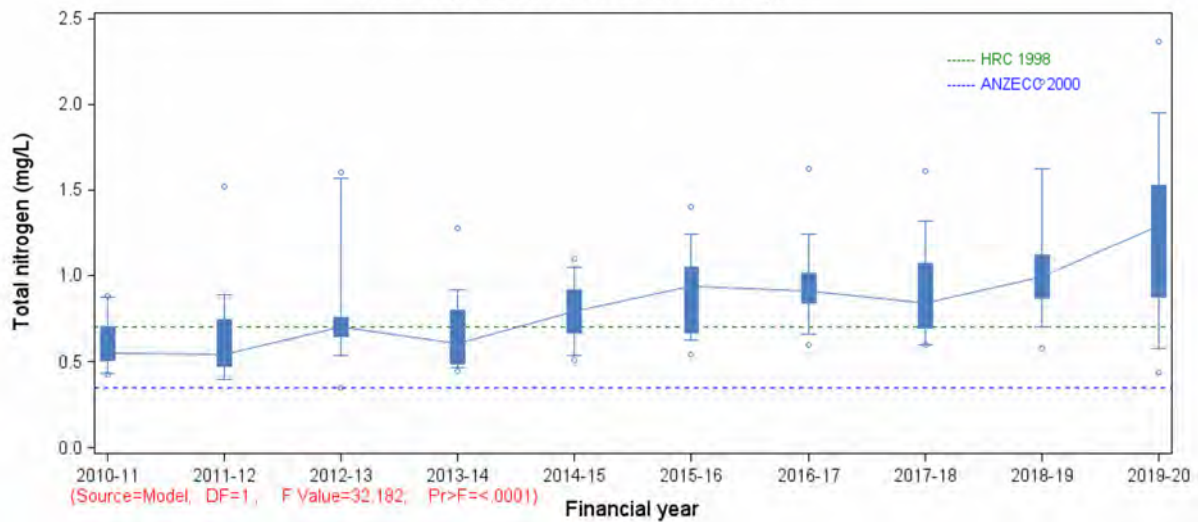
Nutrients, chlorophyll-a and algae



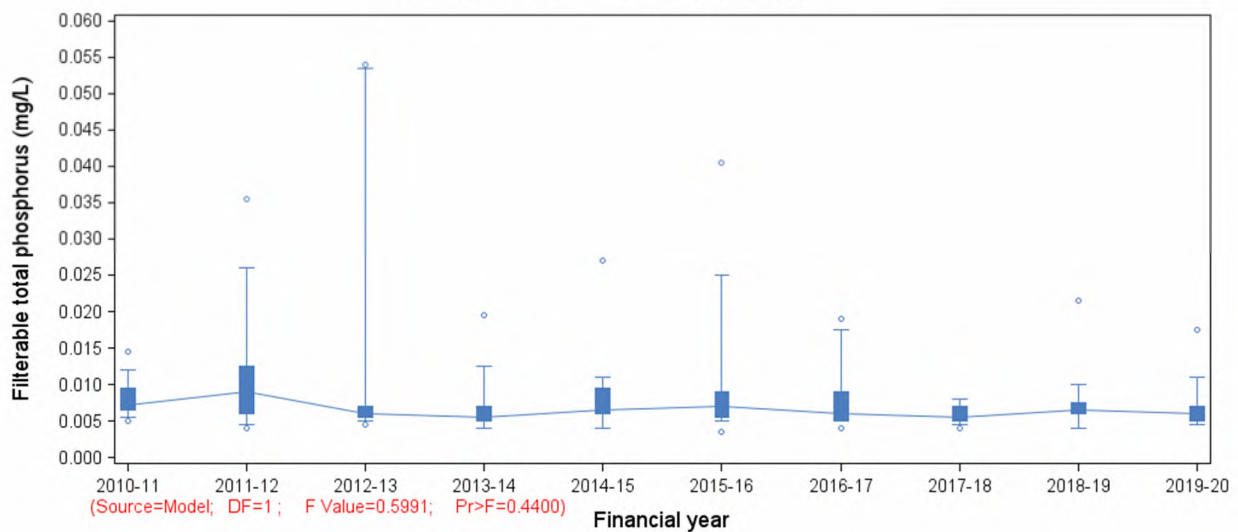
N67: Nepean River at Wallacia Bridge



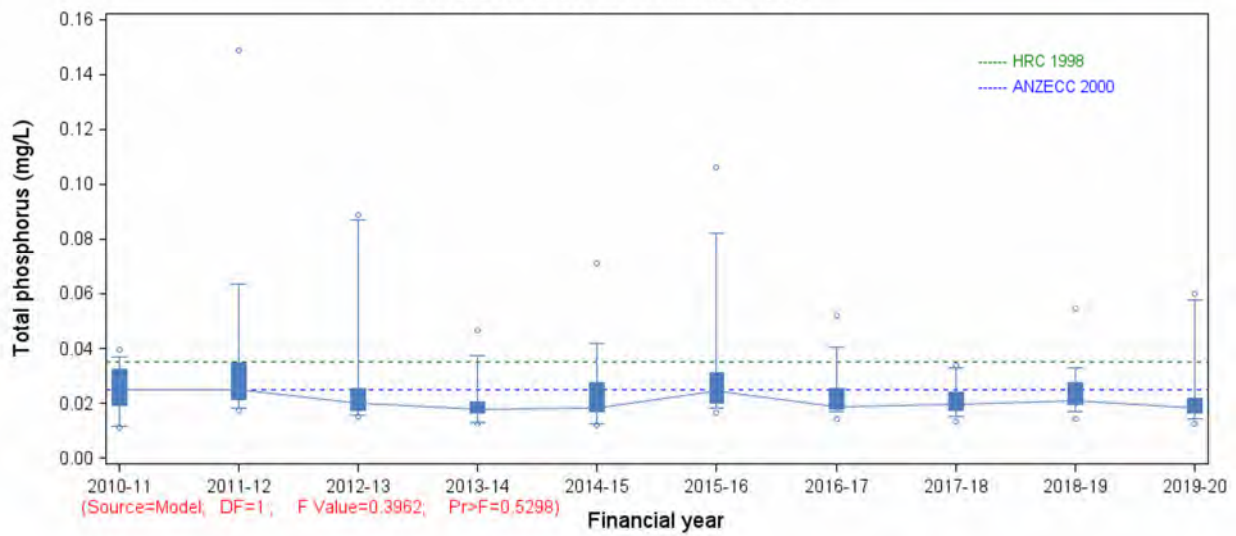
N67: Nepean River at Wallacia Bridge



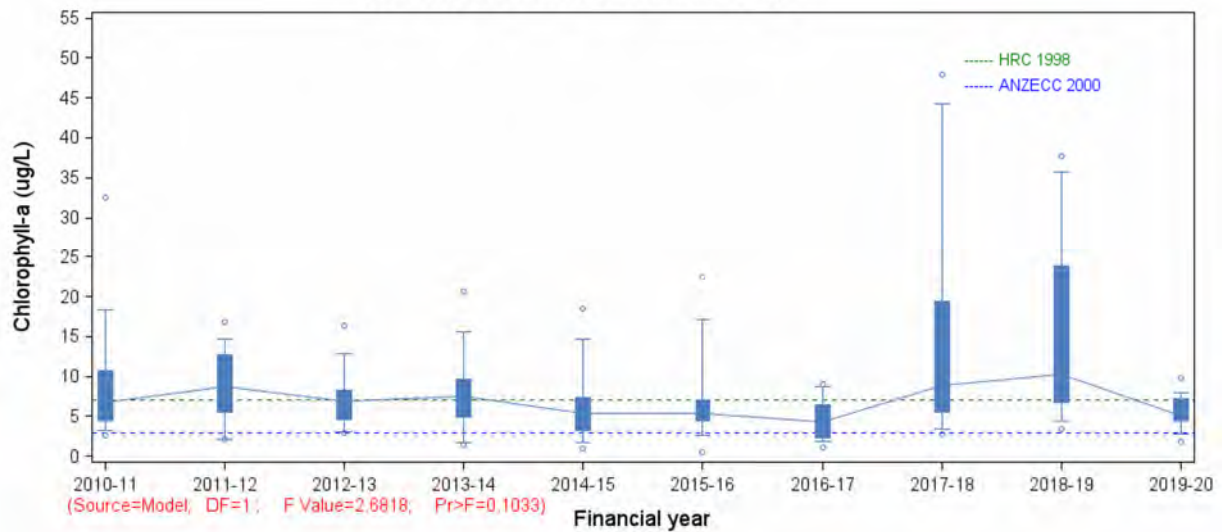
N67: Nepean River at Wallacia Bridge



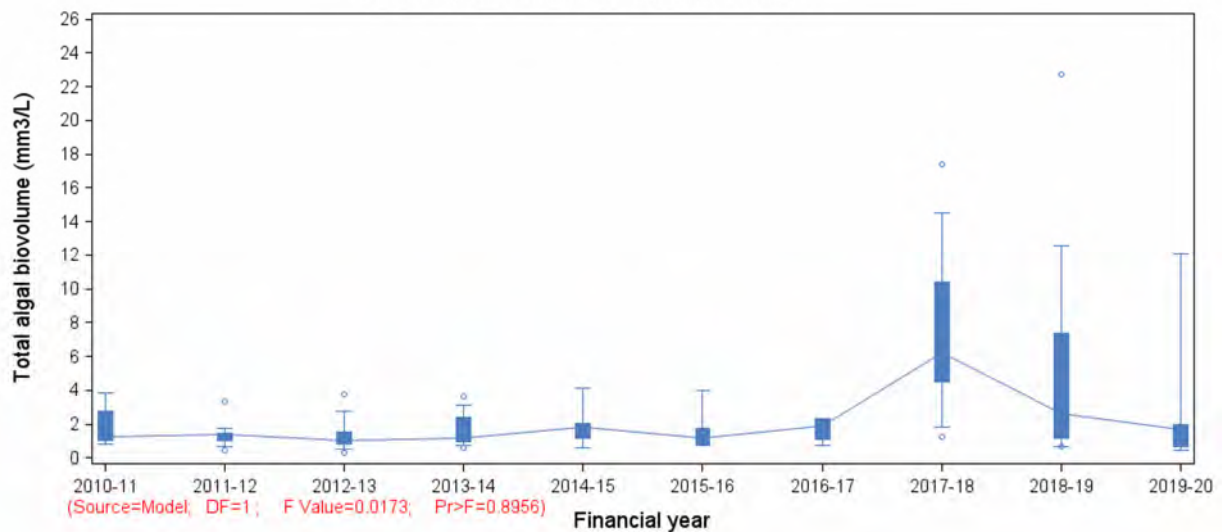
N67: Nepean River at Wallacia Bridge



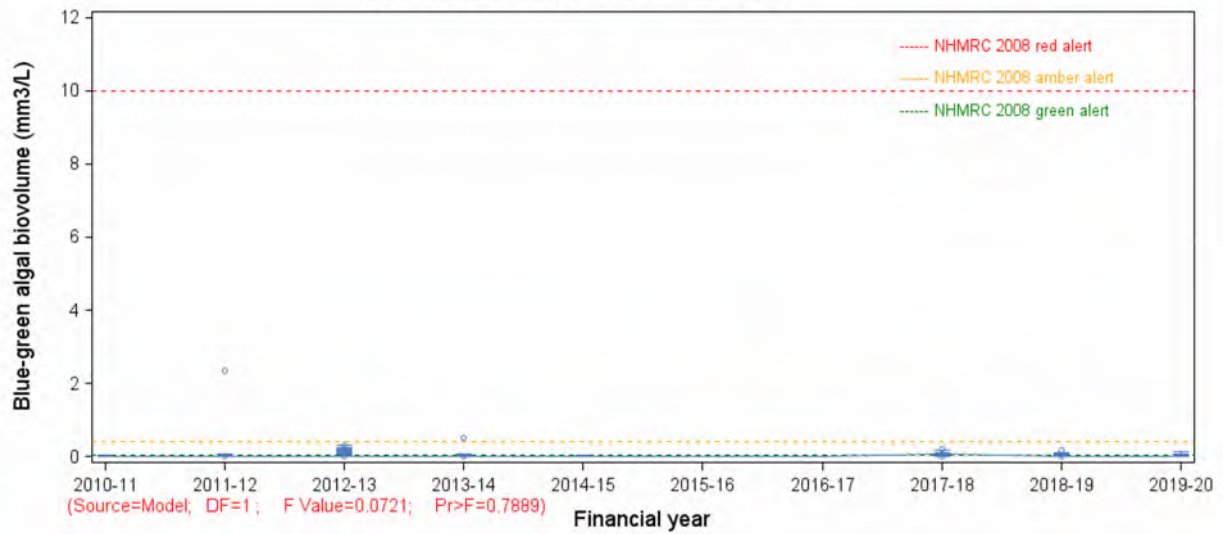
N67: Nepean River at Wallacia Bridge



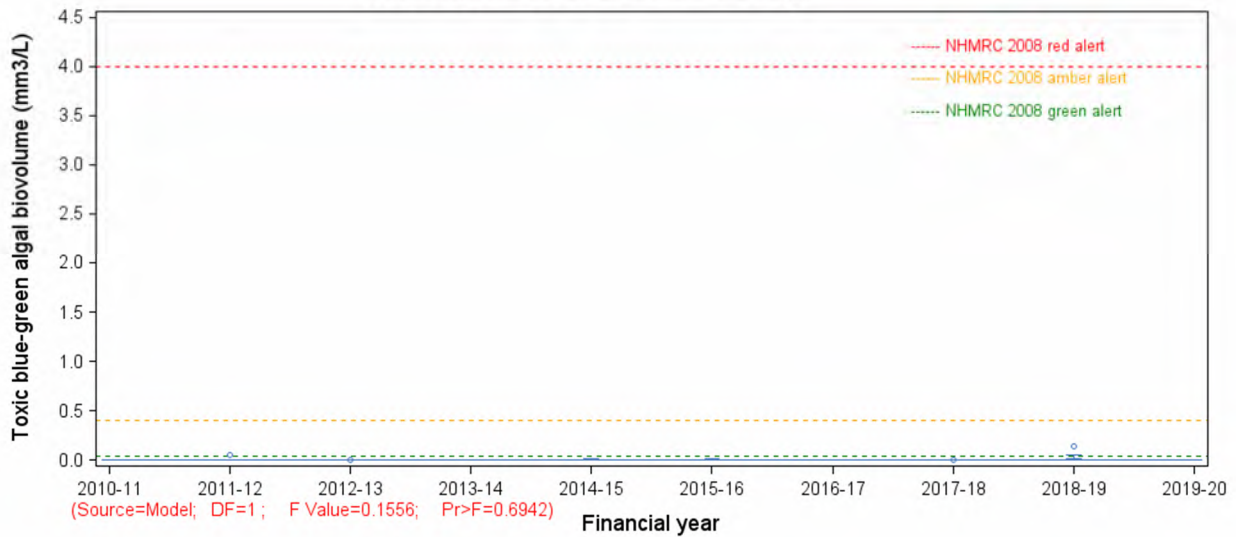
N67: Nepean River at Wallacia Bridge



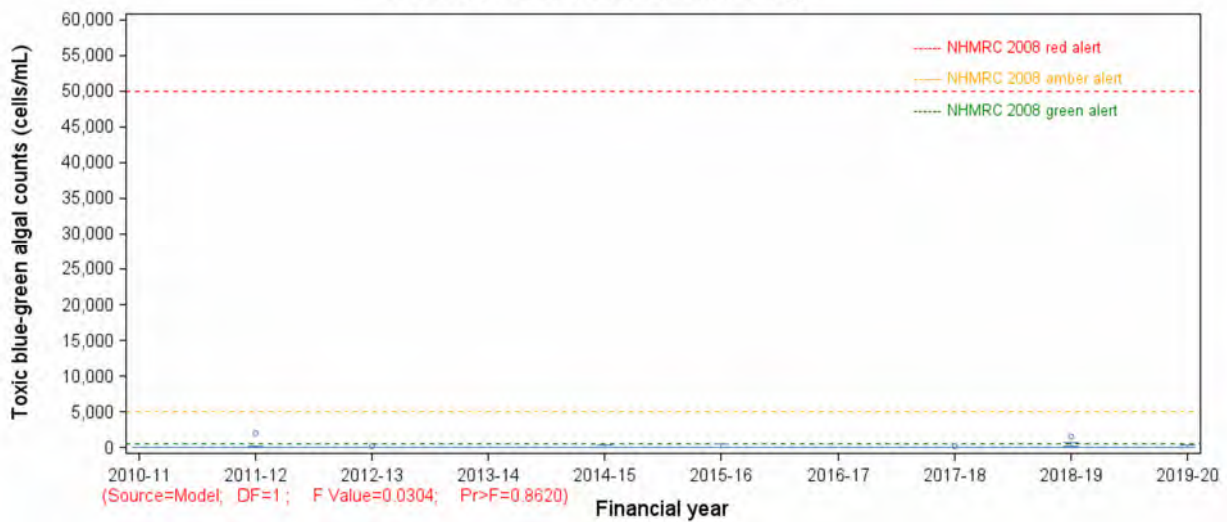
N67: Nepean River at Wallacia Bridge



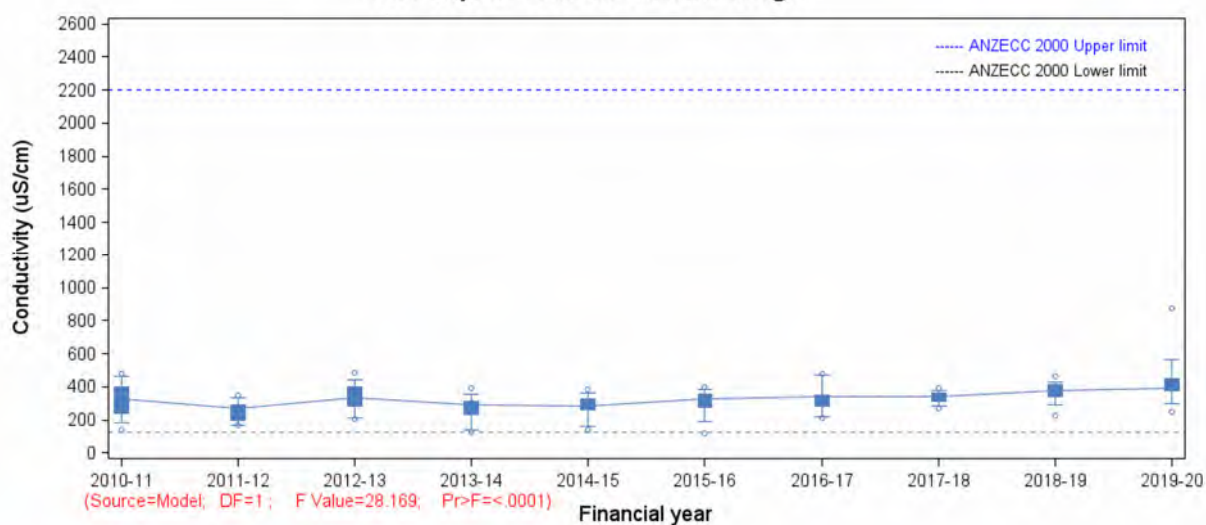
N67: Nepean River at Wallacia Bridge



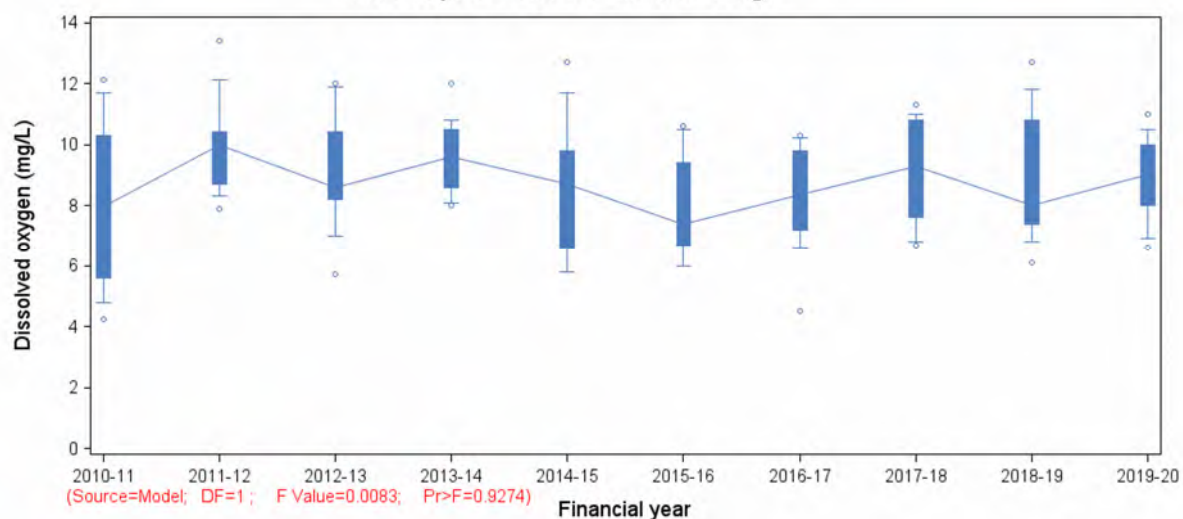
N67: Nepean River at Wallacia Bridge



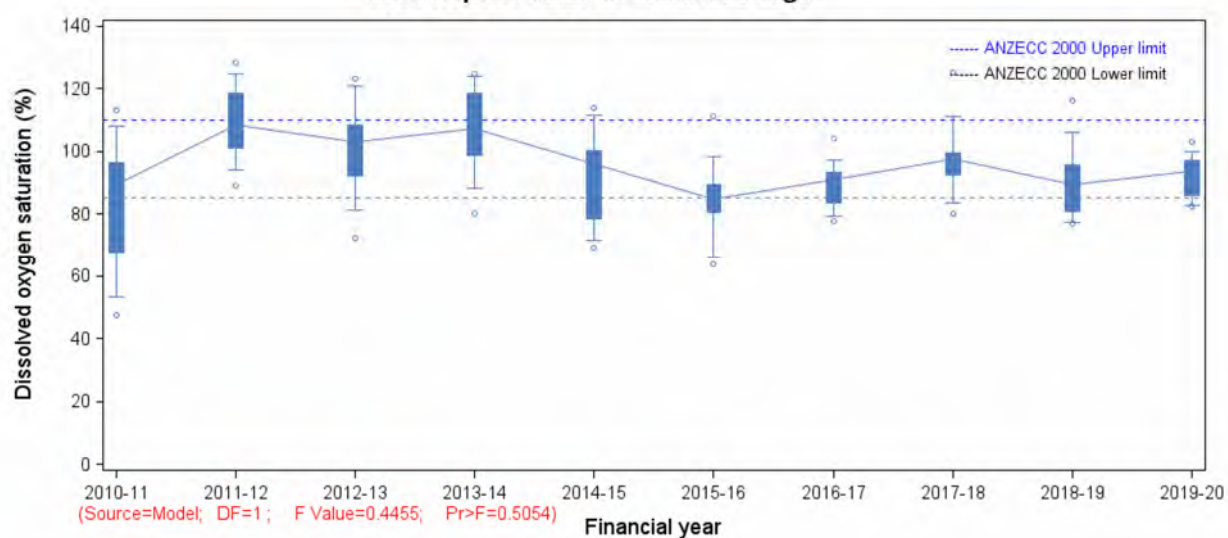
N67: Nepean River at Wallacia Bridge



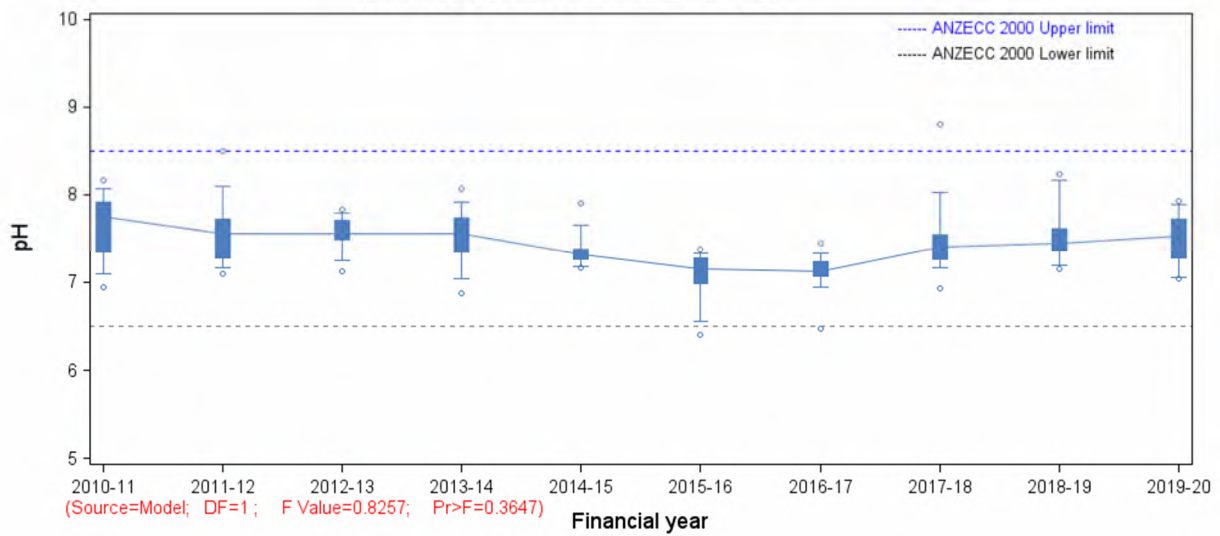
N67: Nepean River at Wallacia Bridge



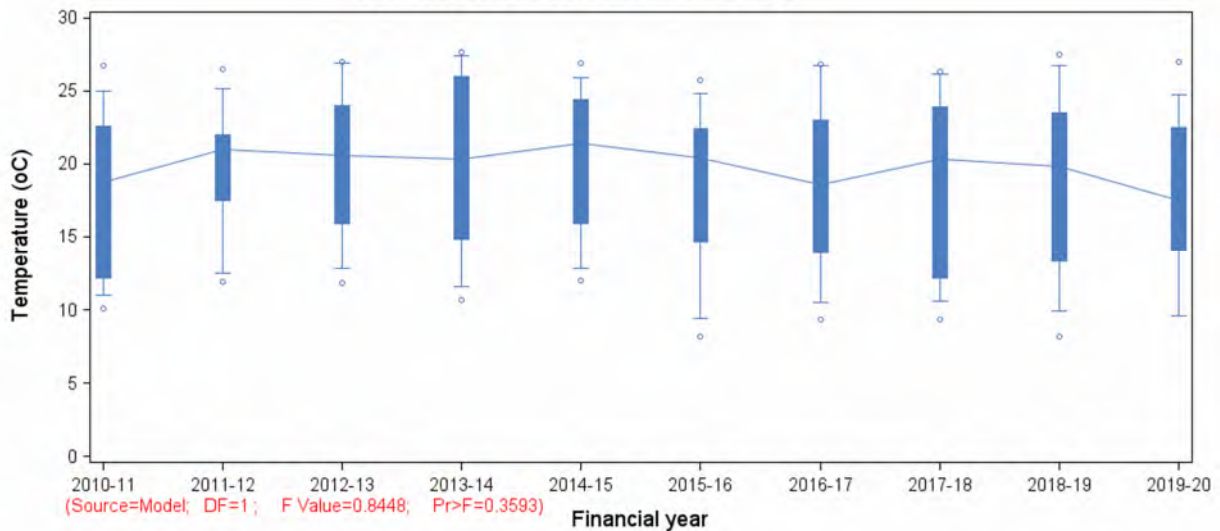
N67: Nepean River at Wallacia Bridge



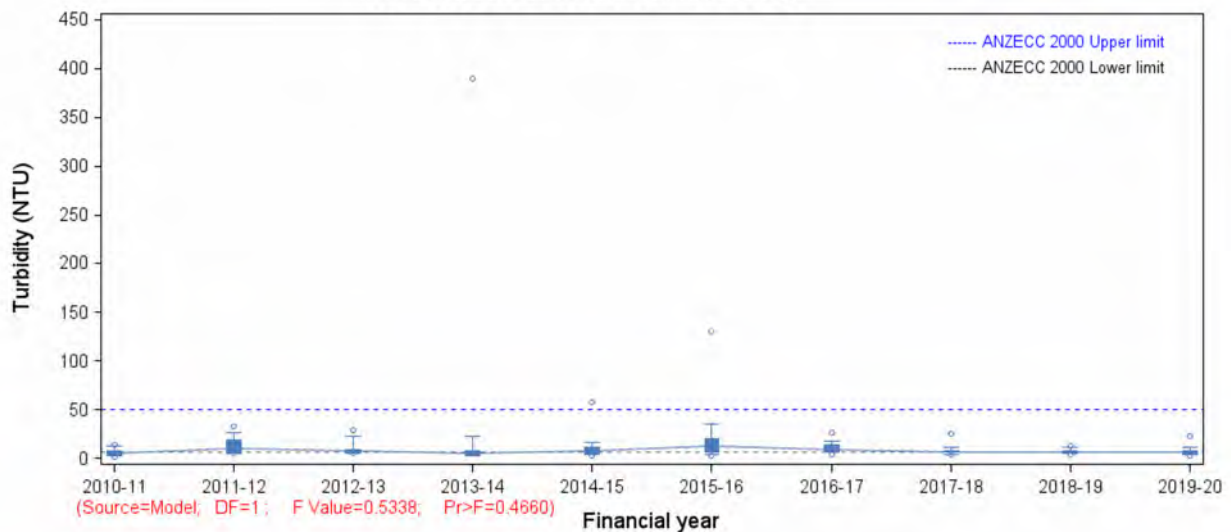
N67: Nepean River at Wallacia Bridge



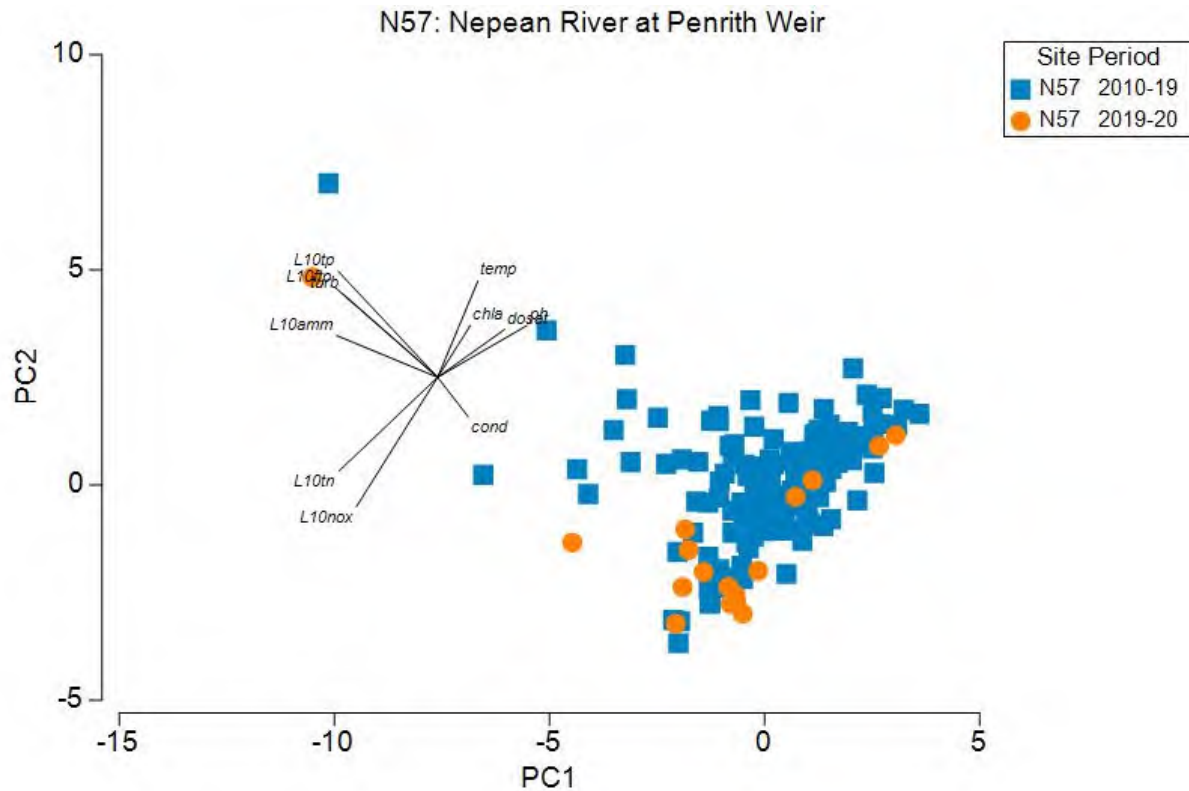
N67: Nepean River at Wallacia Bridge



N67: Nepean River at Wallacia Bridge

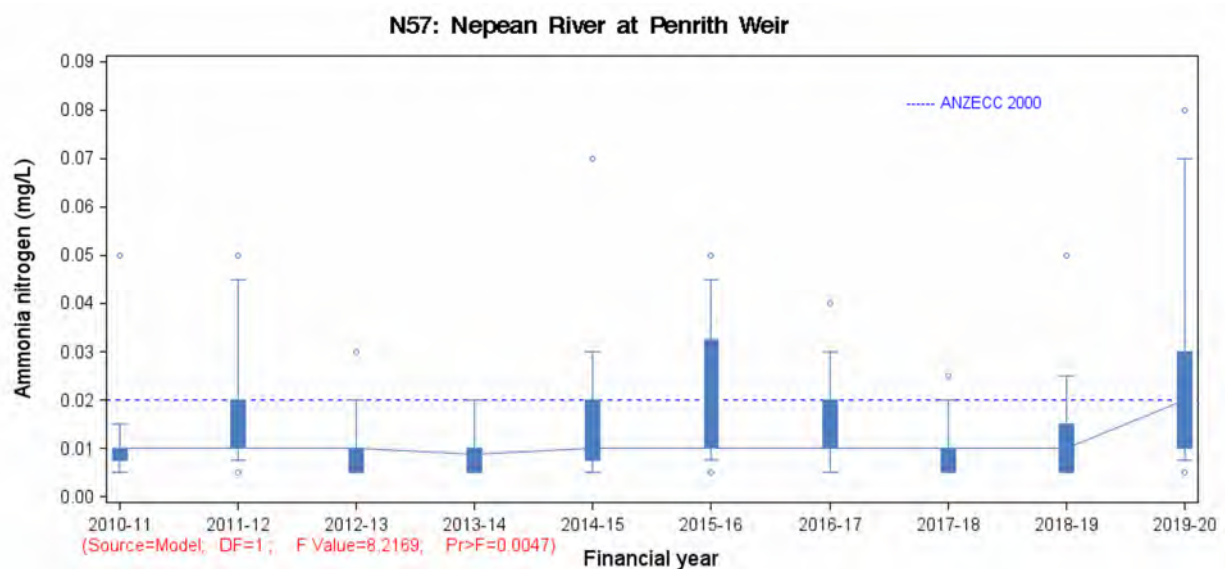


N57: Nepean River at Penrith Weir

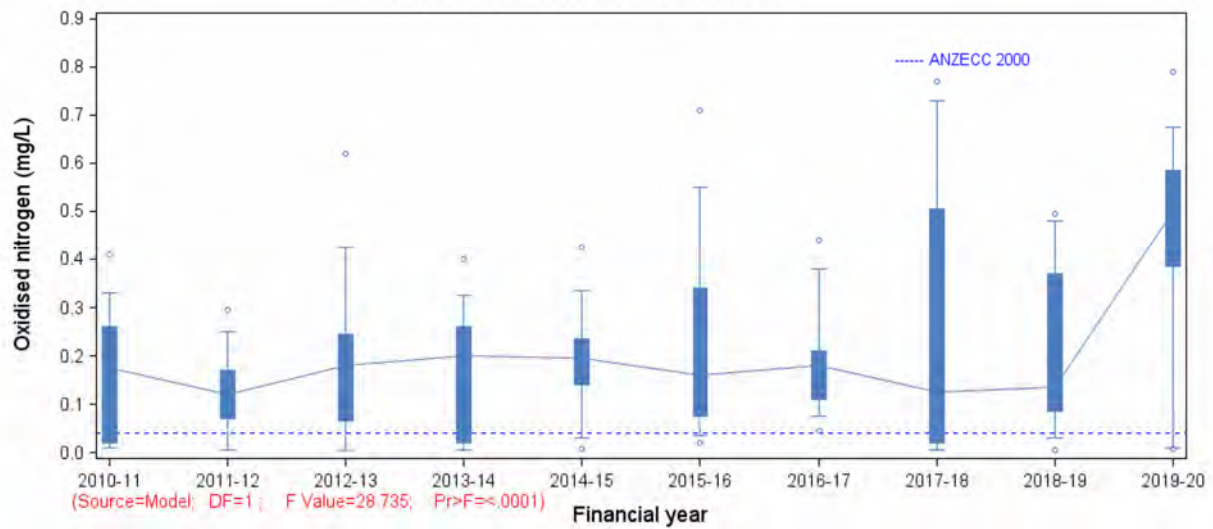


The ordination plot from Principal Components Analysis suggested water quality of the Nepean River at Penrith Weir in 2019-20 was similar to that recorded in the period 2010 to 2019.

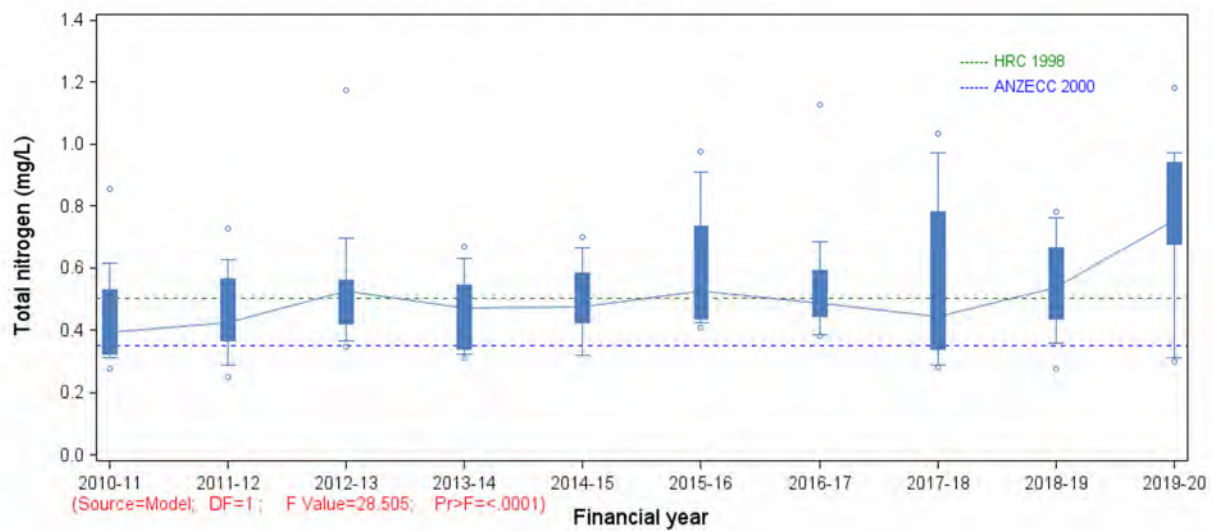
Nutrients, chlorophyll-a and algae



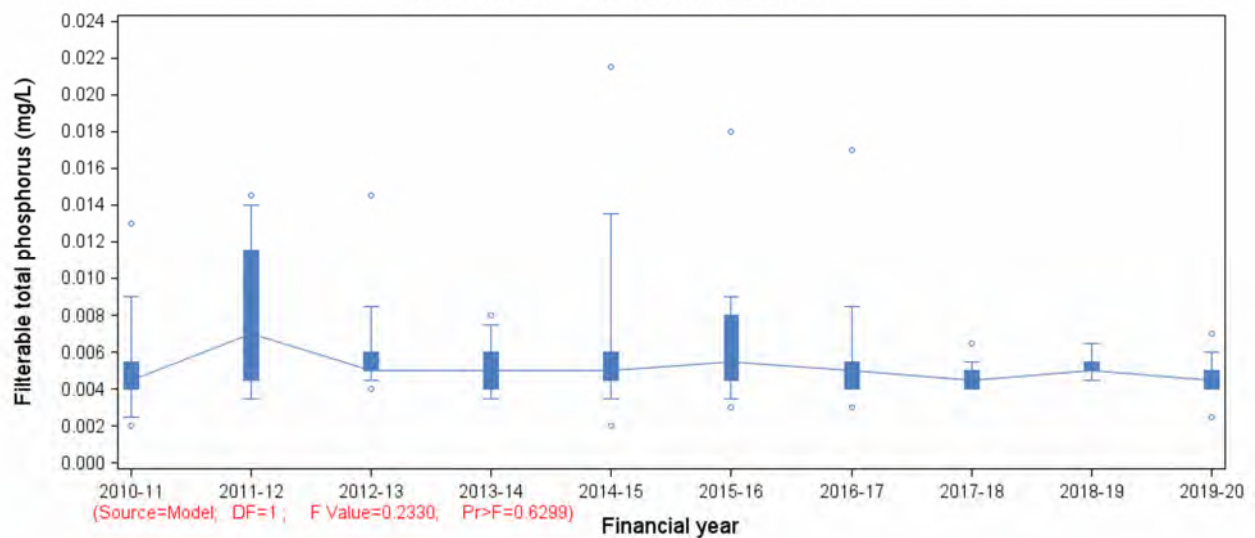
N57: Nepean River at Penrith Weir



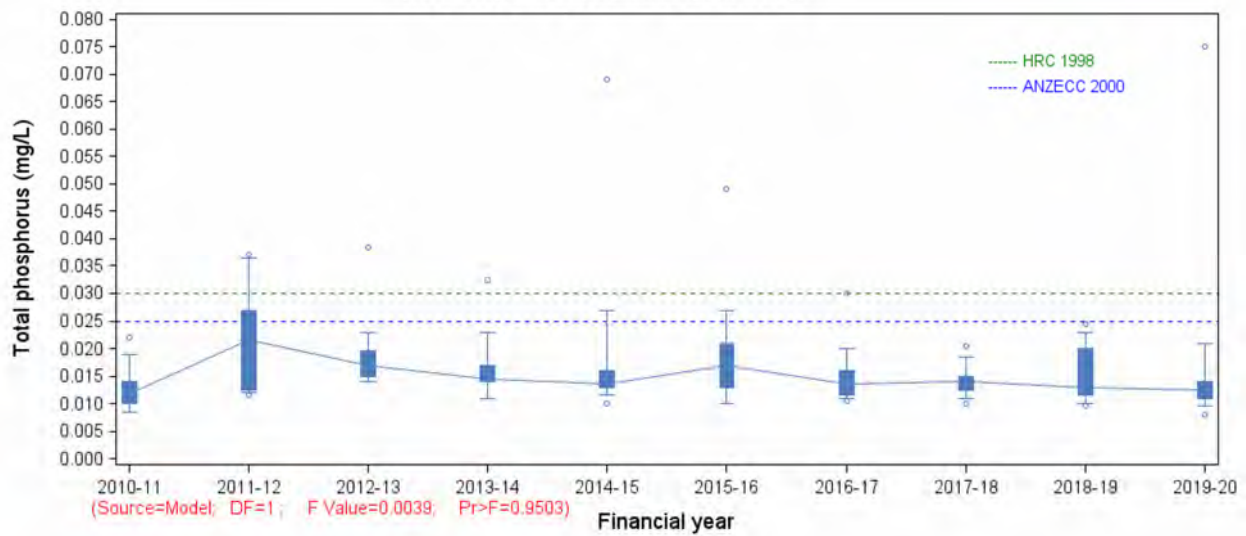
N57: Nepean River at Penrith Weir



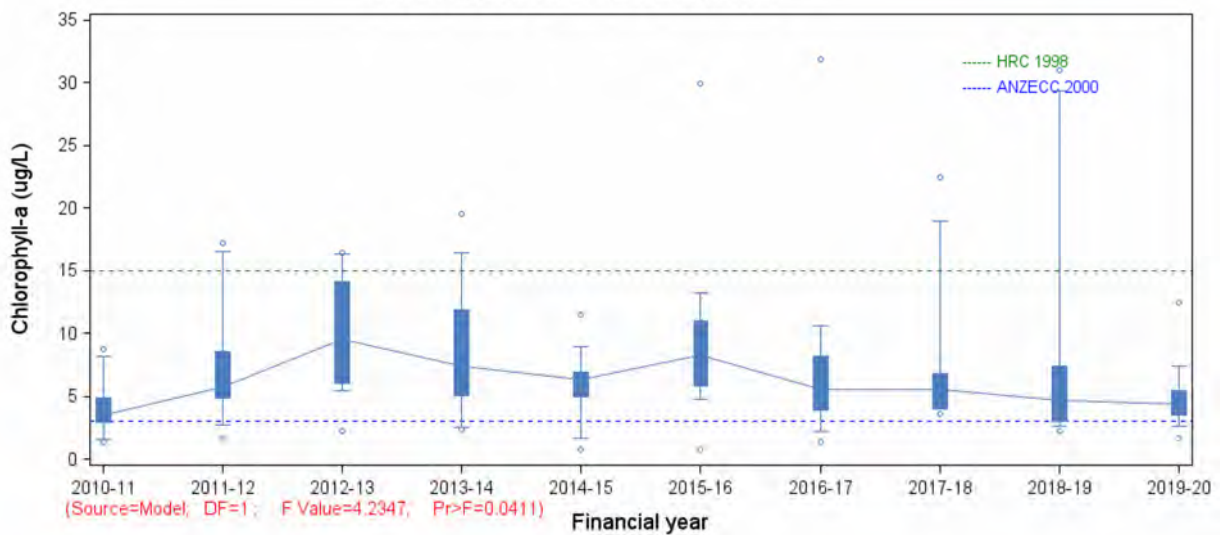
N57: Nepean River at Penrith Weir



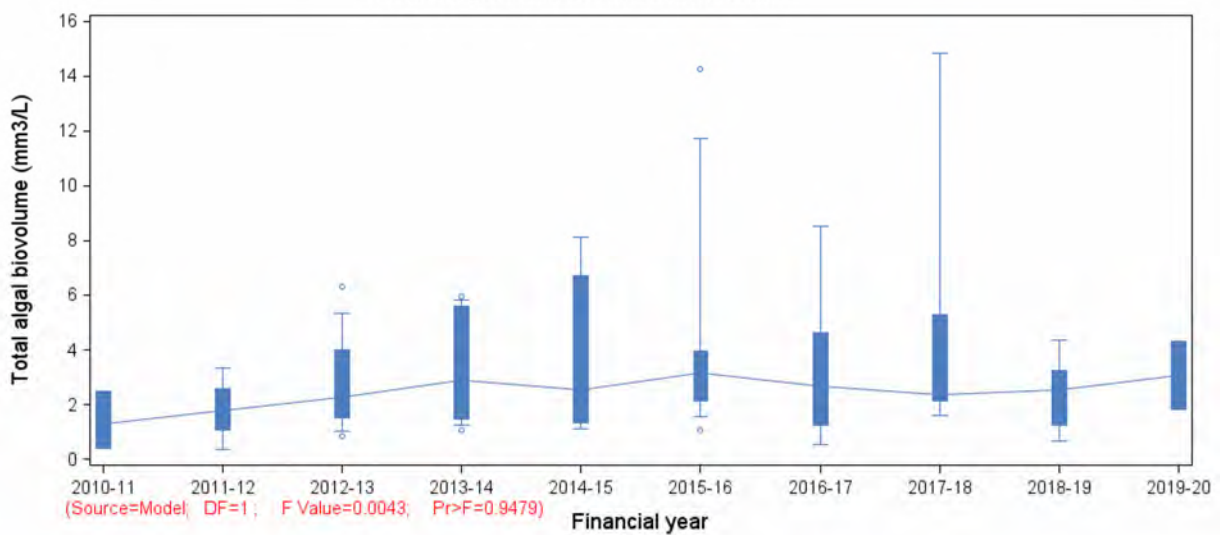
N57: Nepean River at Penrith Weir



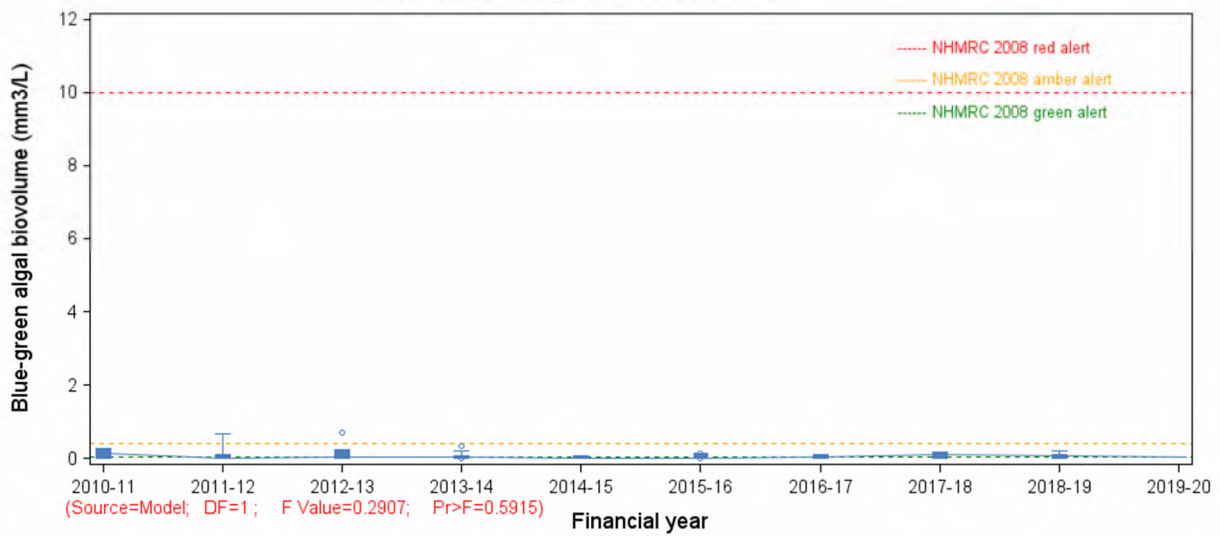
N57: Nepean River at Penrith Weir



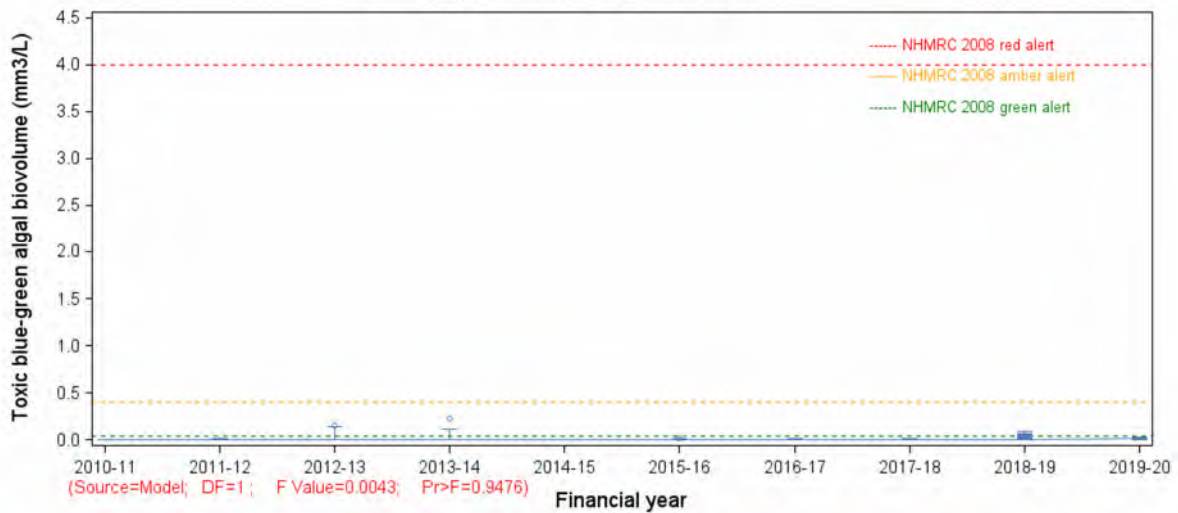
N57: Nepean River at Penrith Weir



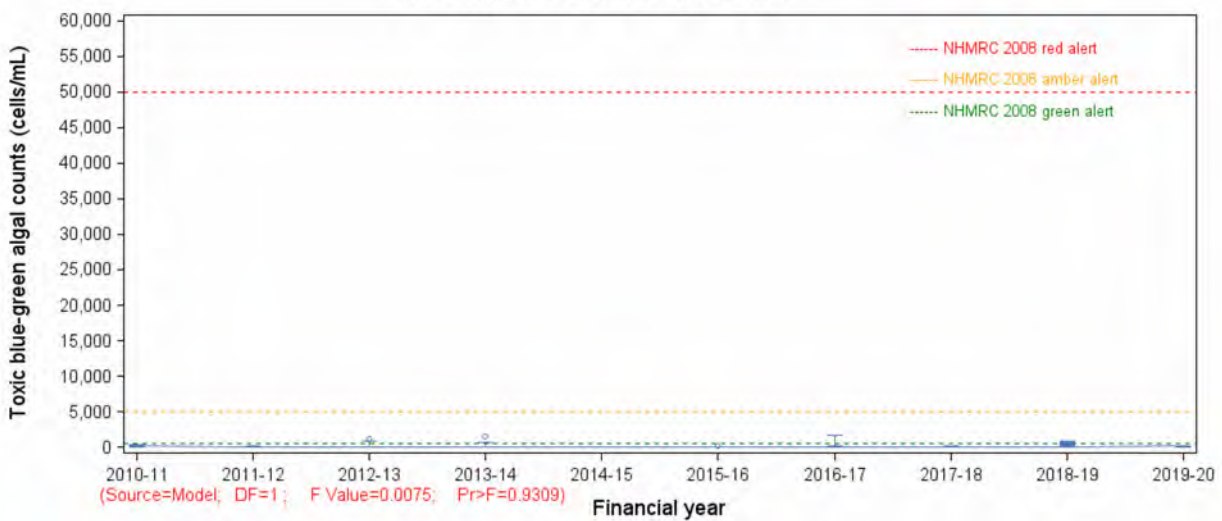
N57: Nepean River at Penrith Weir



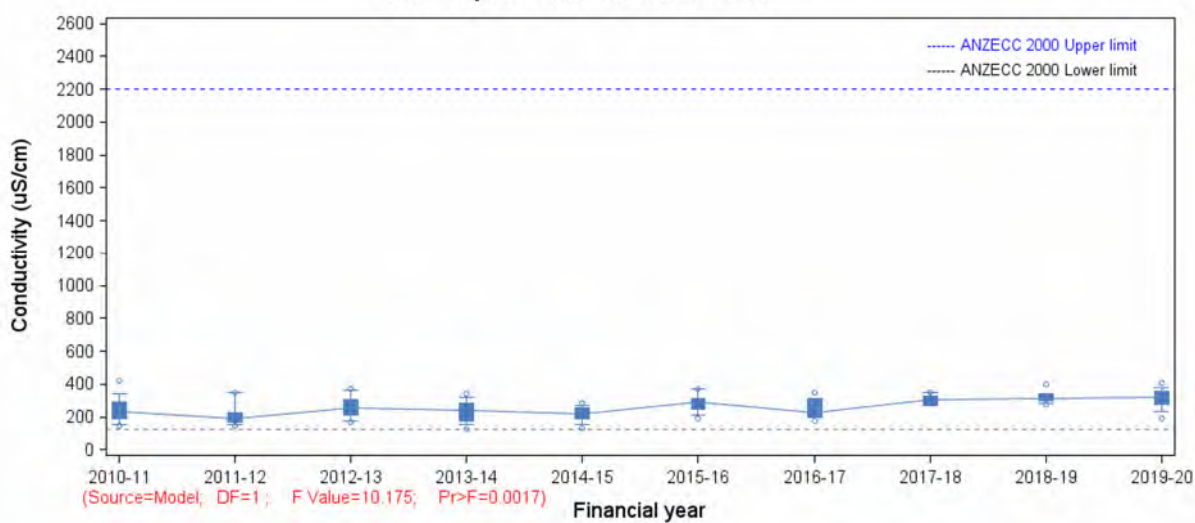
N57: Nepean River at Penrith Weir



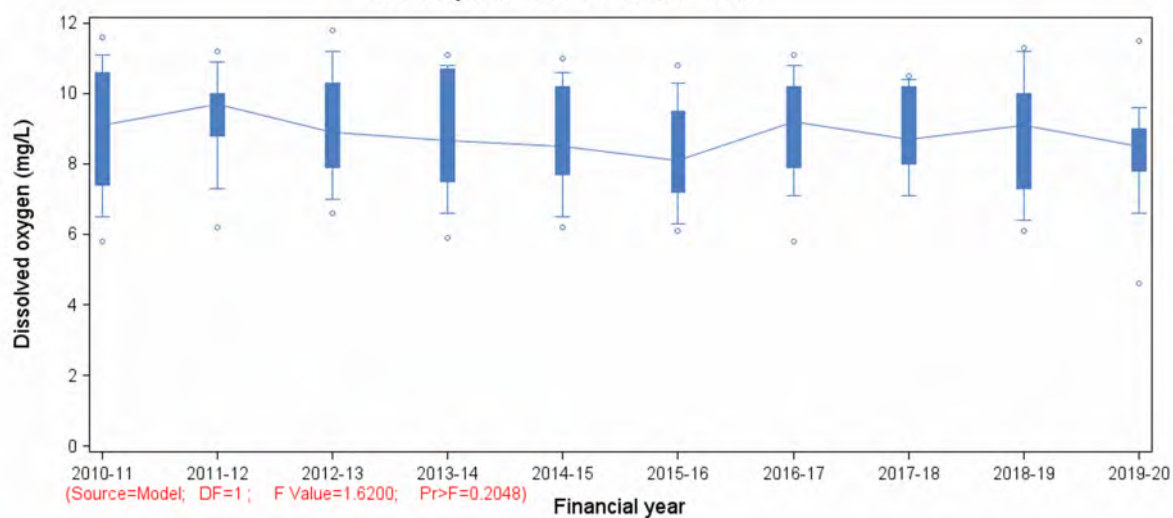
N57: Nepean River at Penrith Weir



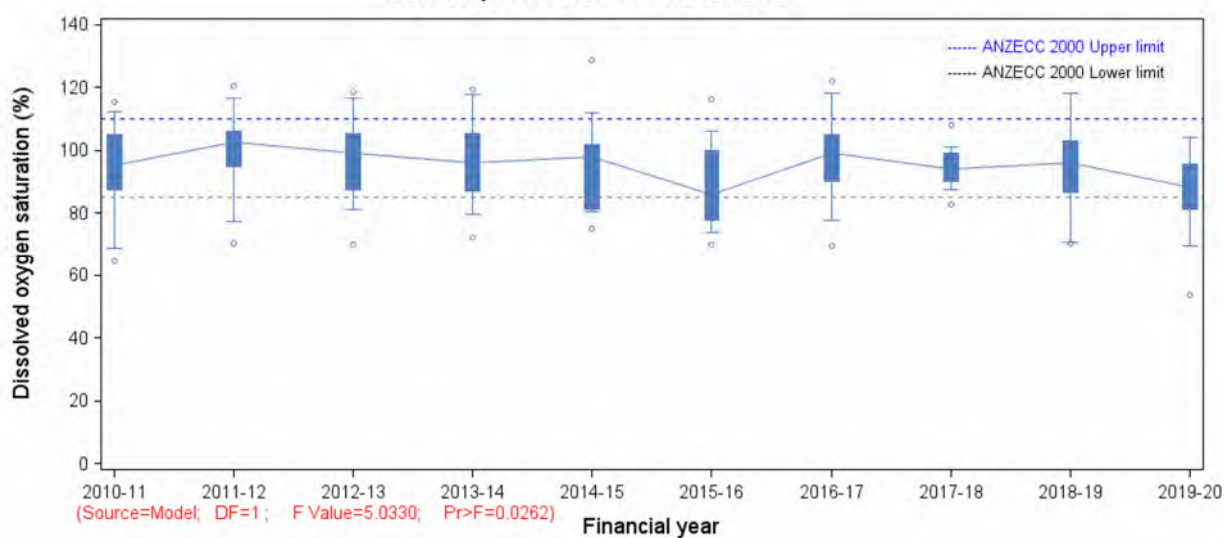
N57: Nepean River at Penrith Weir



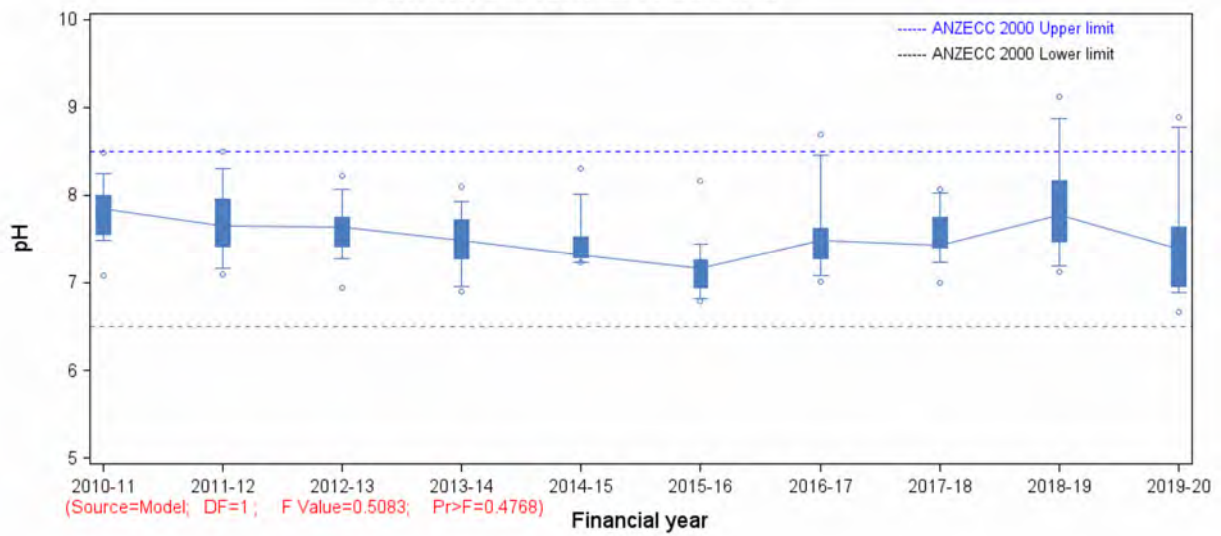
N57: Nepean River at Penrith Weir



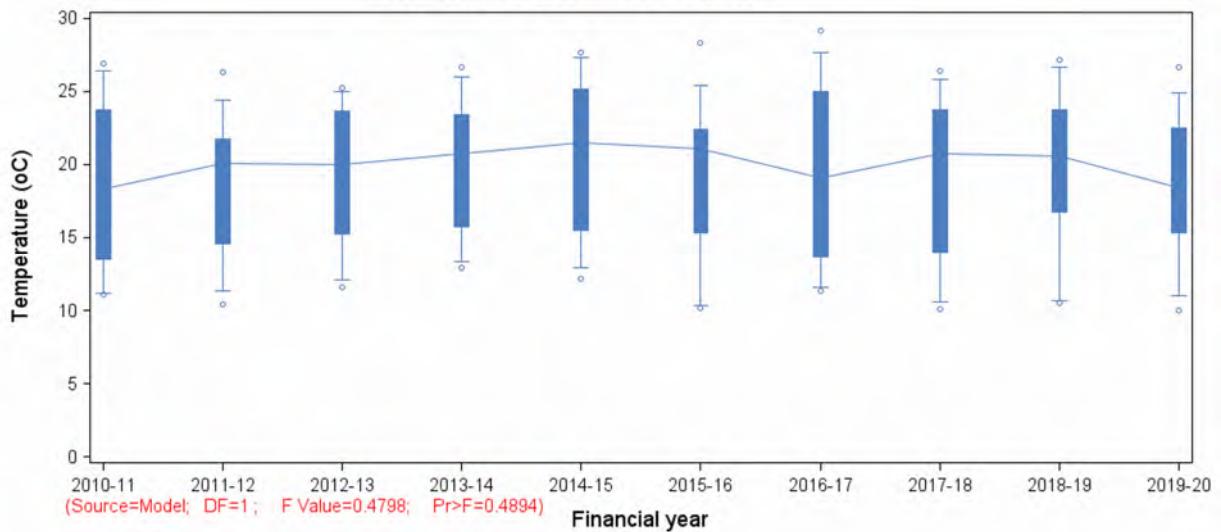
N57: Nepean River at Penrith Weir



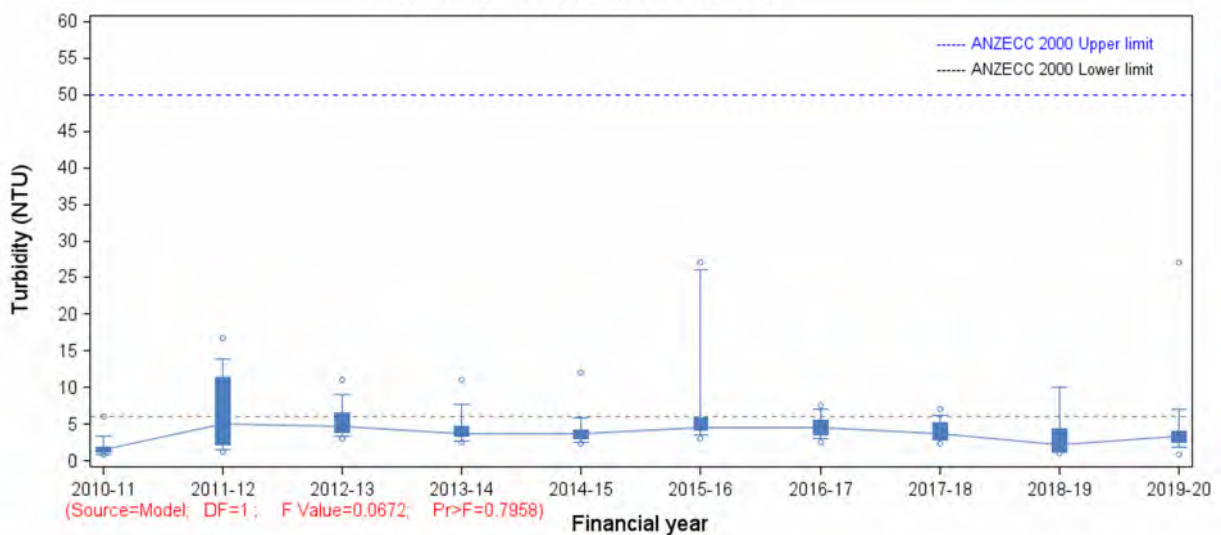
N57: Nepean River at Penrith Weir



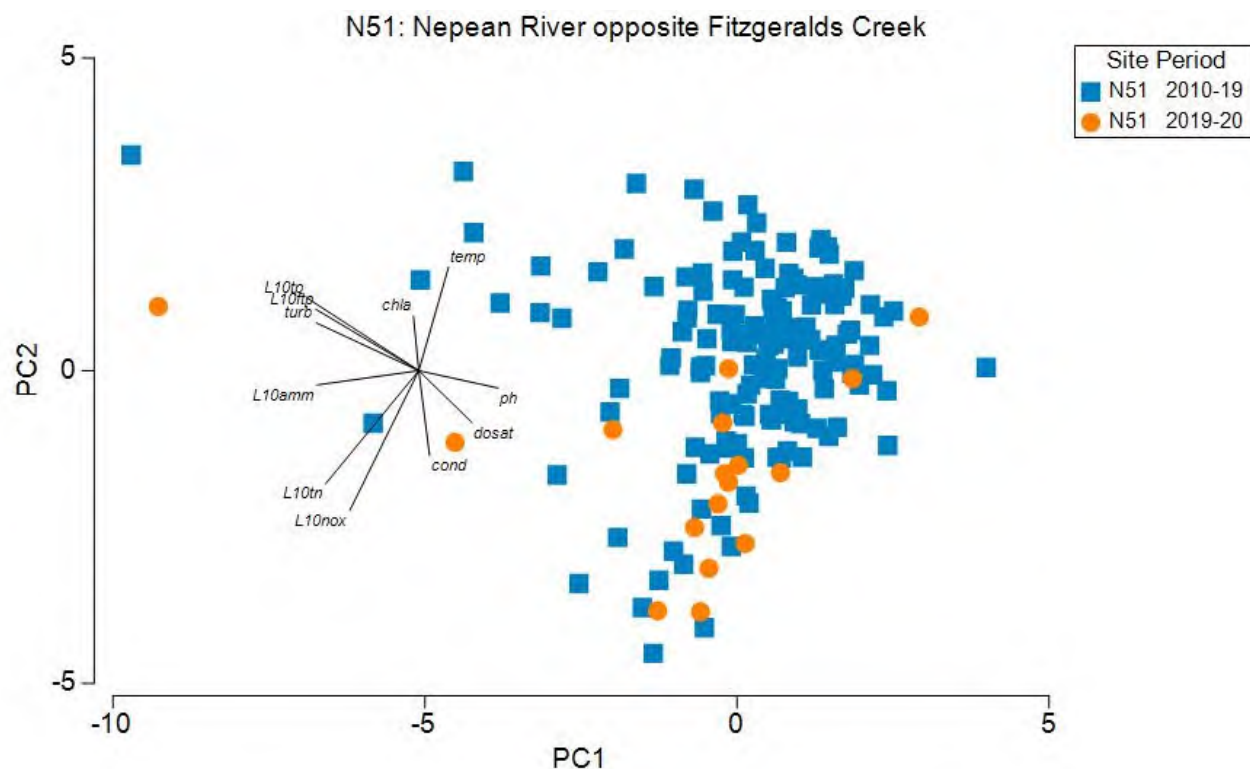
N57: Nepean River at Penrith Weir



N57: Nepean River at Penrith Weir

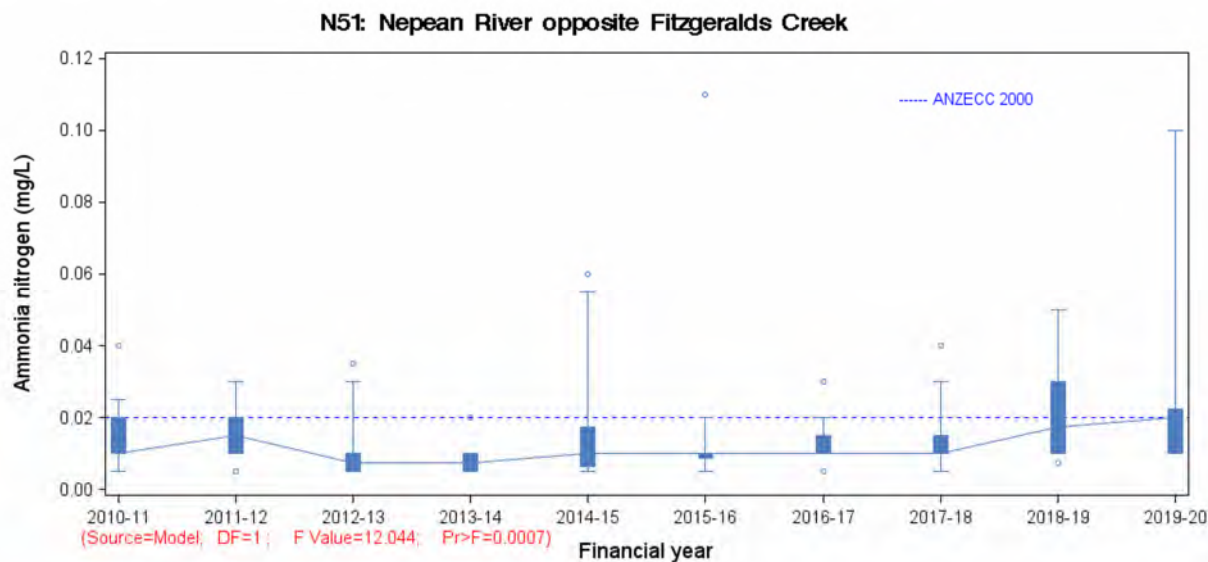


N51: Nepean River opposite Fitzgerald Creek

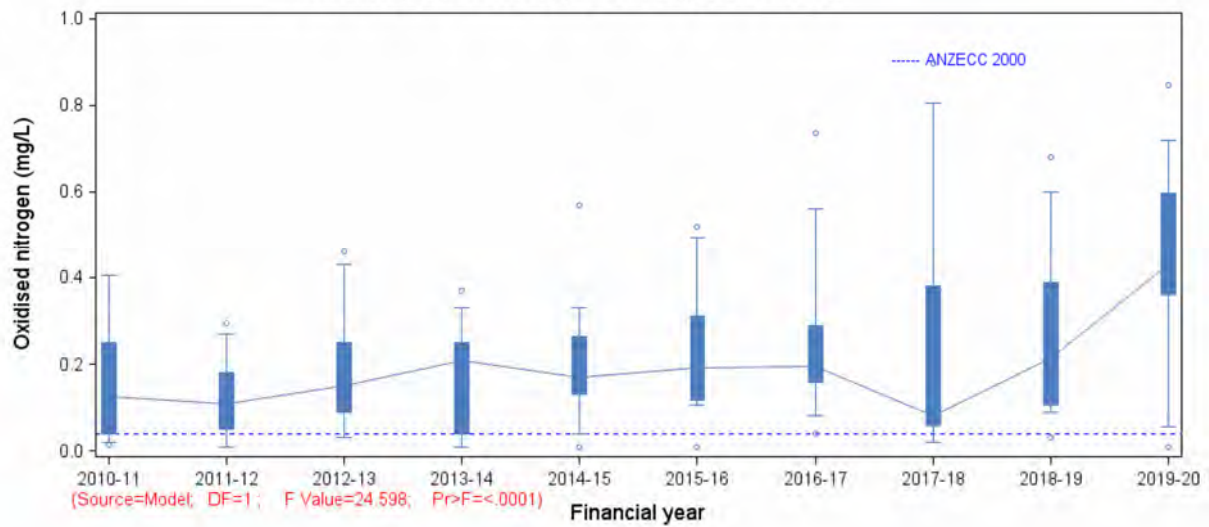


The ordination plot from Principal Components Analysis suggested water quality of the Nepean River opposite Fitzgeralds Creek in 2019-20 was similar to that recorded in the period 2010 to 2019.

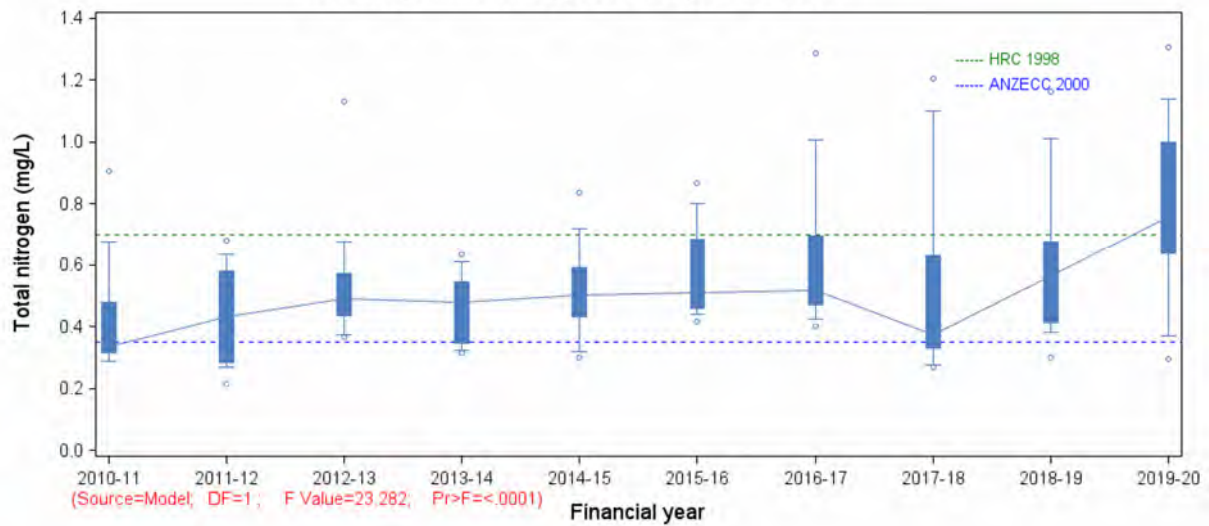
Nutrients, chlorophyll-a and algae



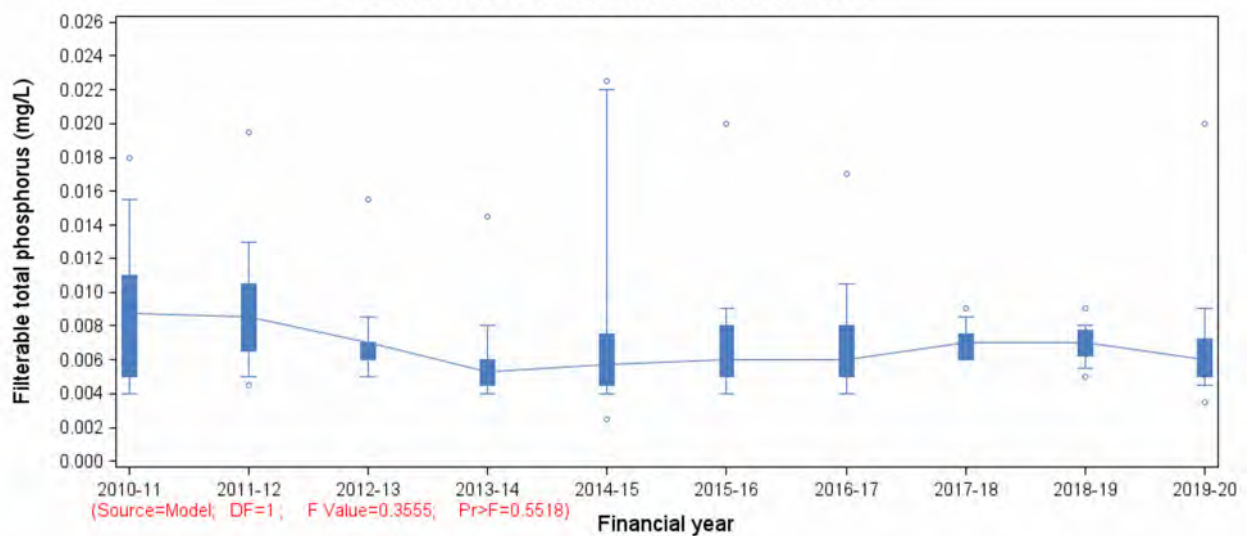
N51: Nepean River opposite Fitzgeralds Creek



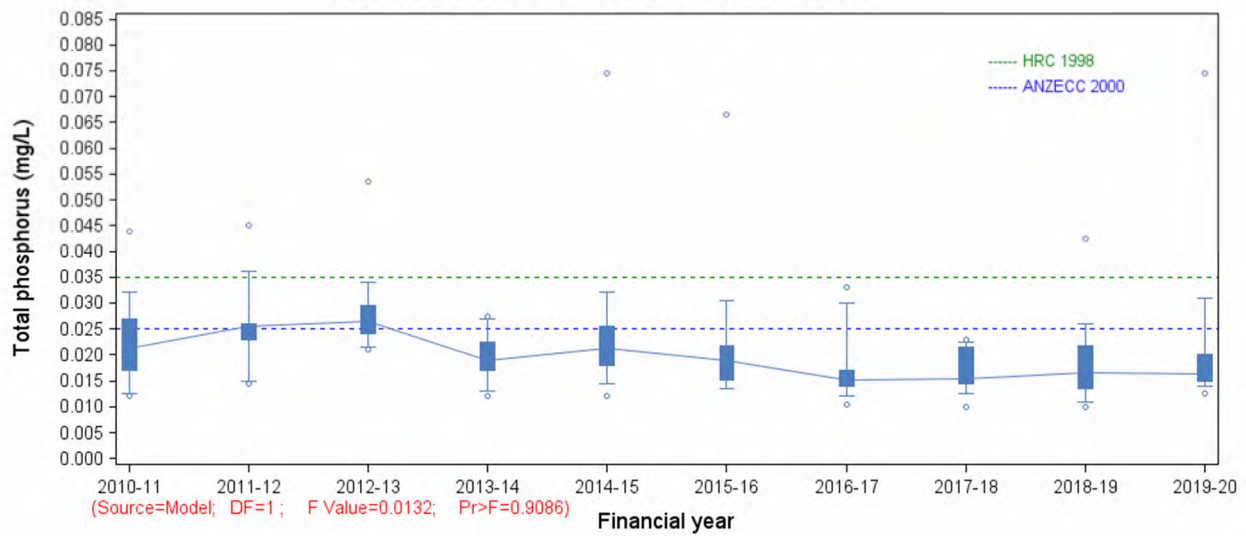
N51: Nepean River opposite Fitzgeralds Creek



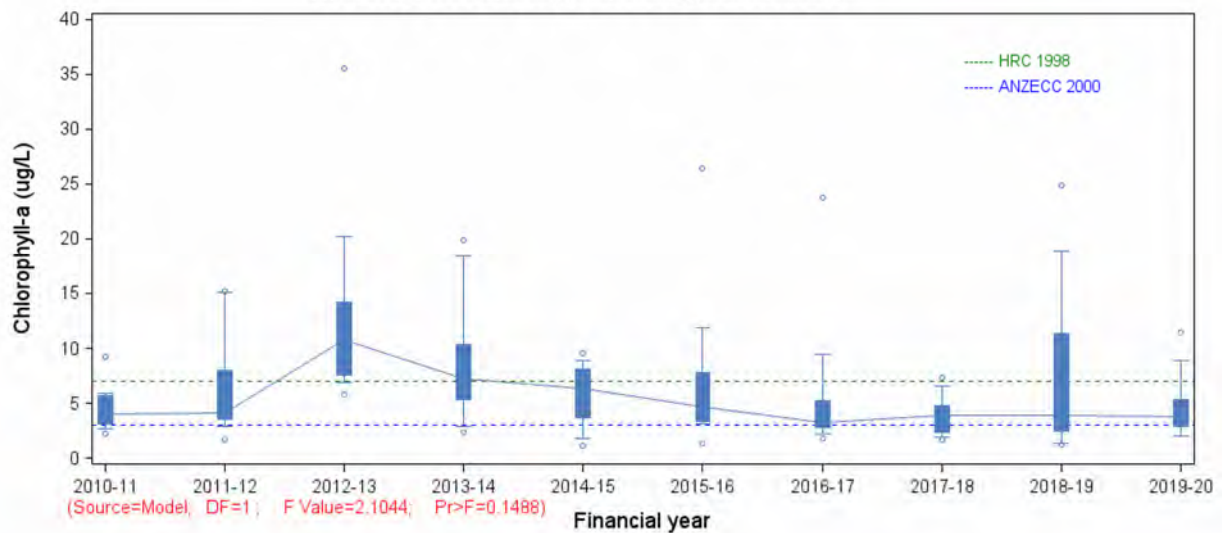
N51: Nepean River opposite Fitzgeralds Creek



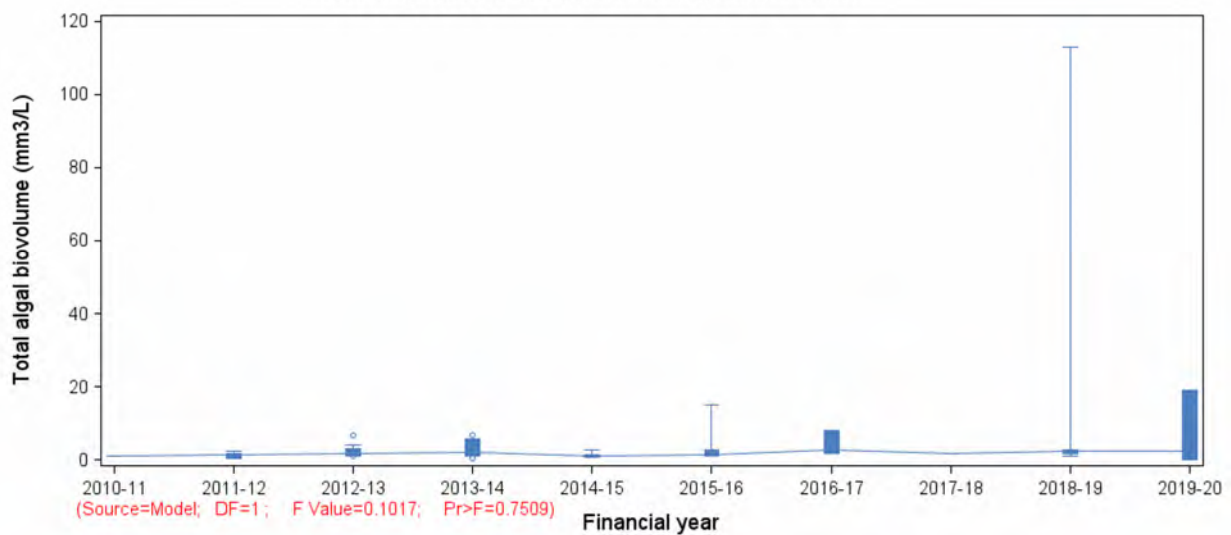
N51: Nepean River opposite Fitzgeralds Creek



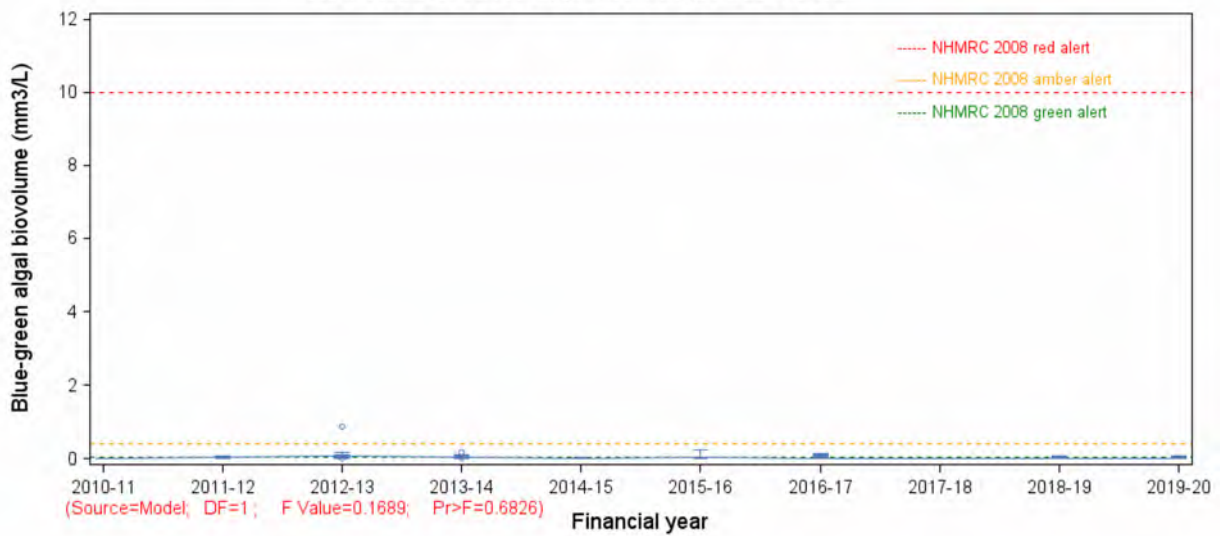
N51: Nepean River opposite Fitzgeralds Creek



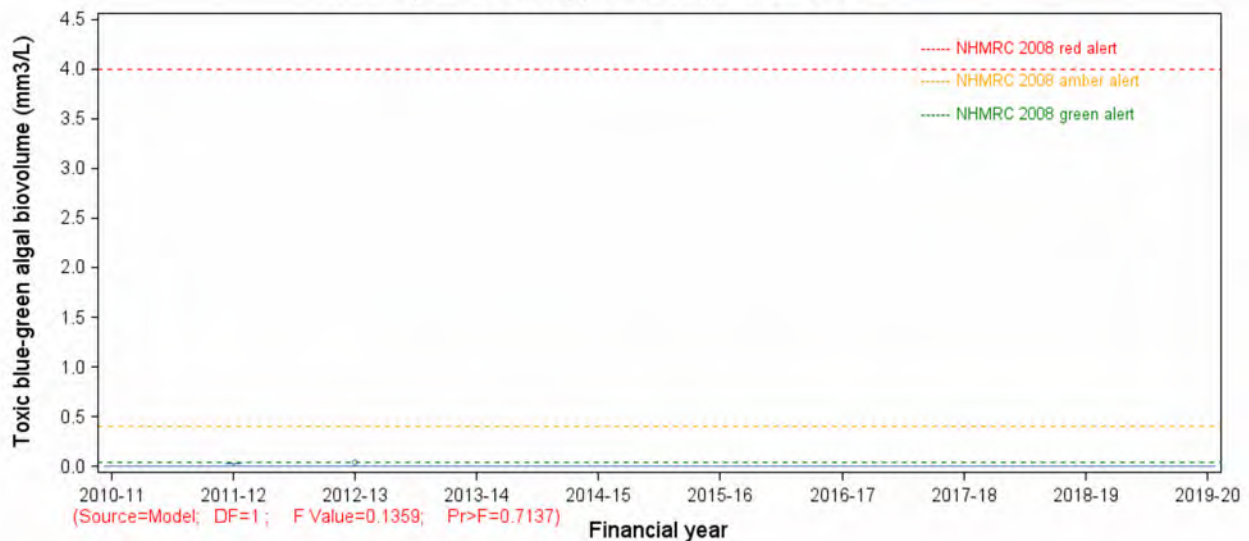
N51: Nepean River opposite Fitzgeralds Creek



N51: Nepean River opposite Fitzgeralds Creek

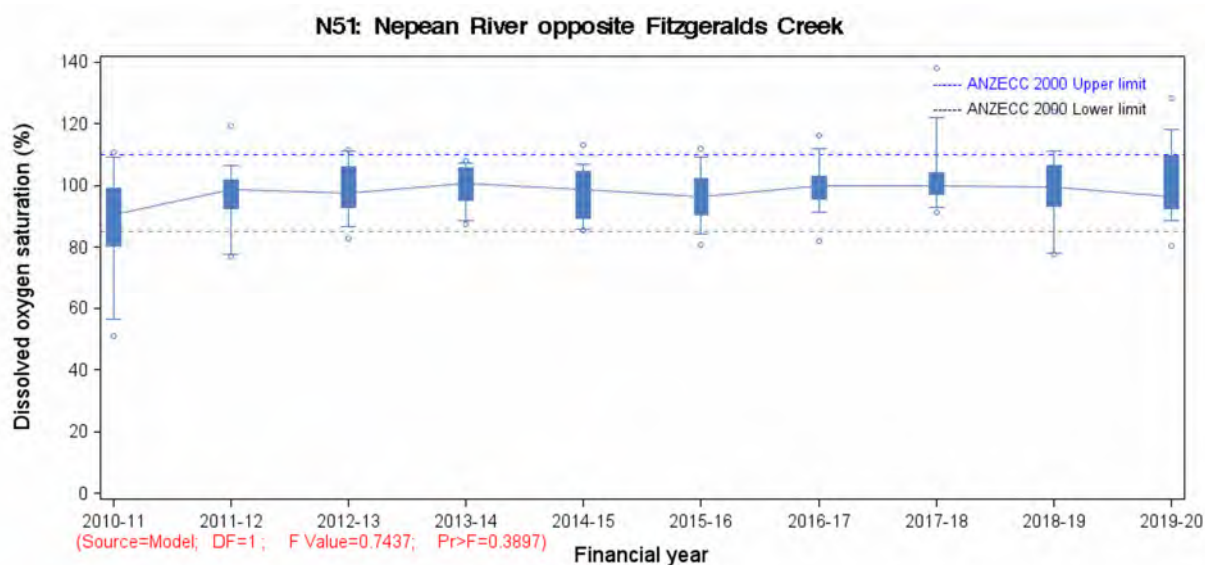
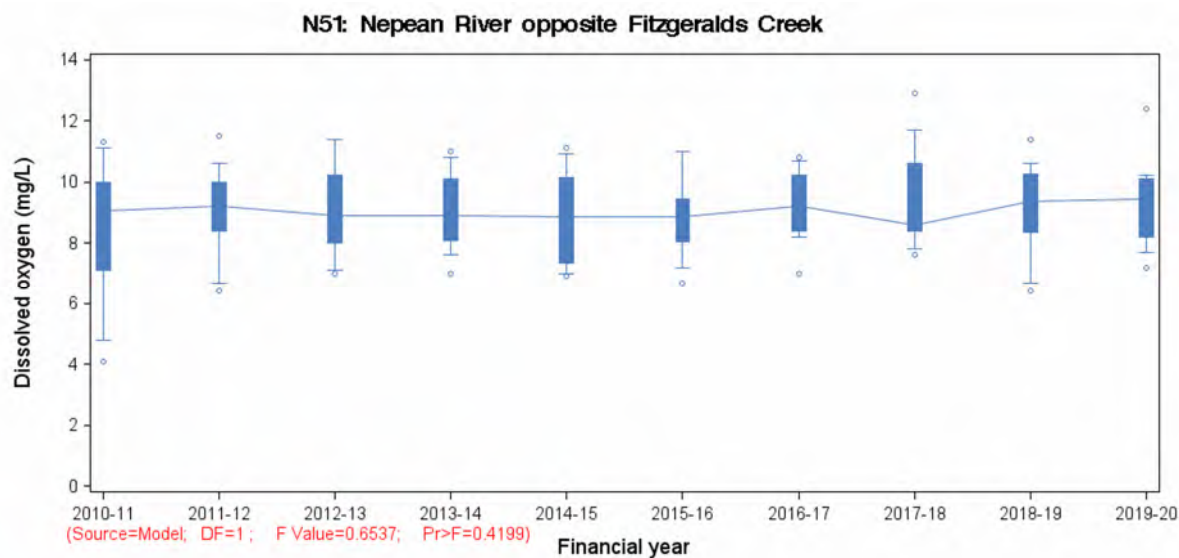
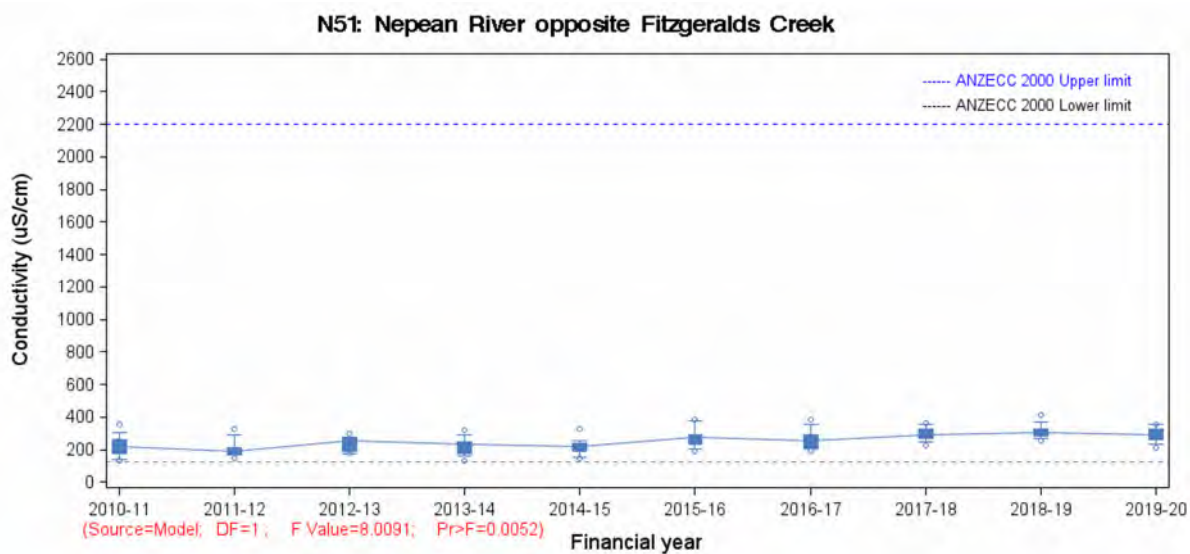


N51: Nepean River opposite Fitzgeralds Creek

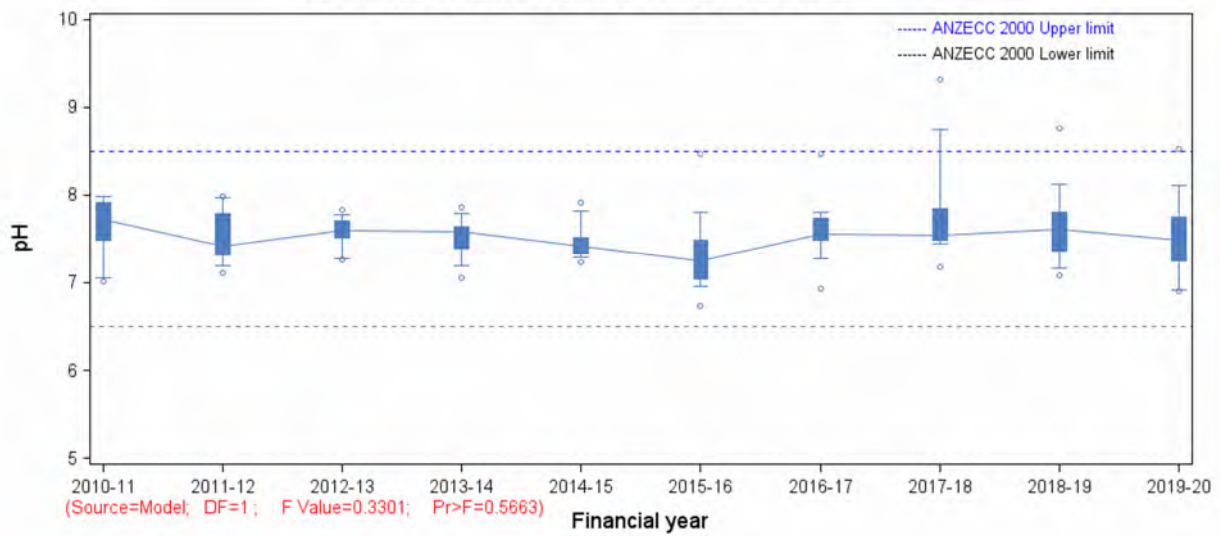


N51: Nepean River opposite Fitzgeralds Creek

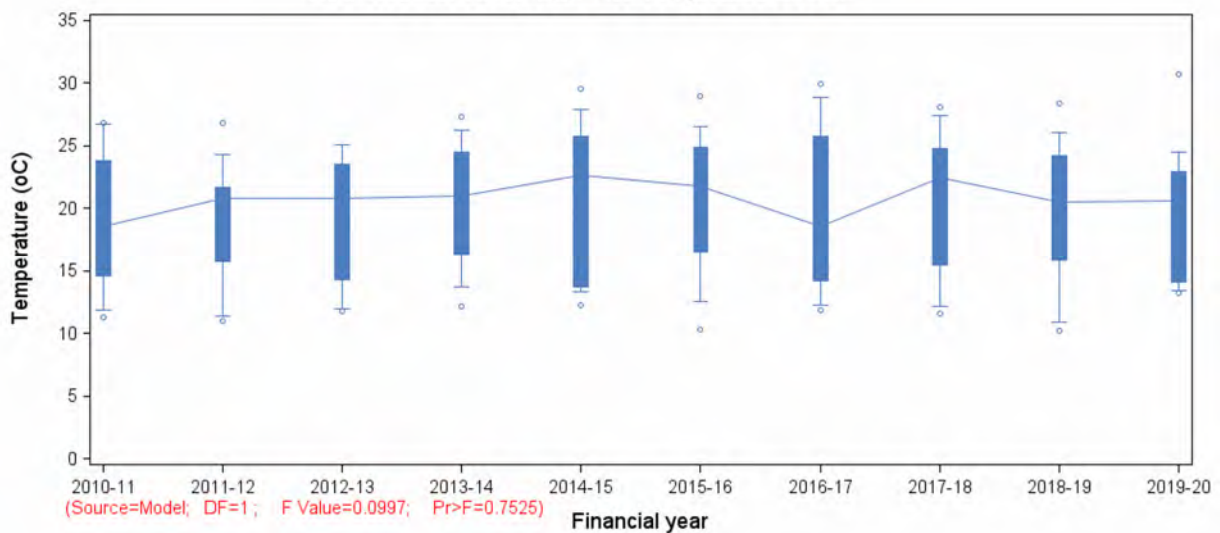




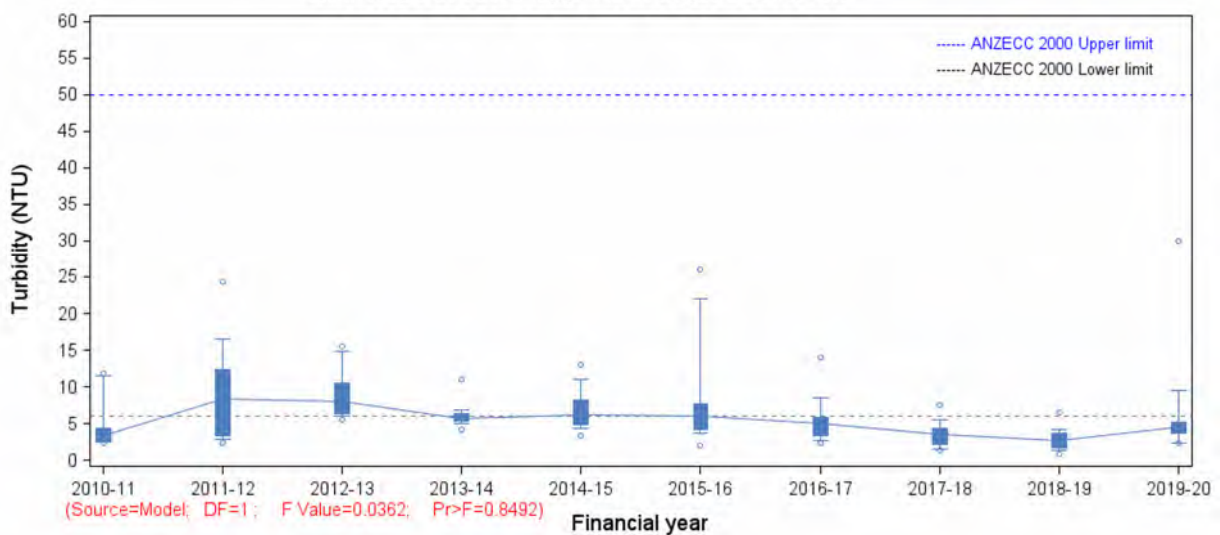
N51: Nepean River opposite Fitzgeralds Creek



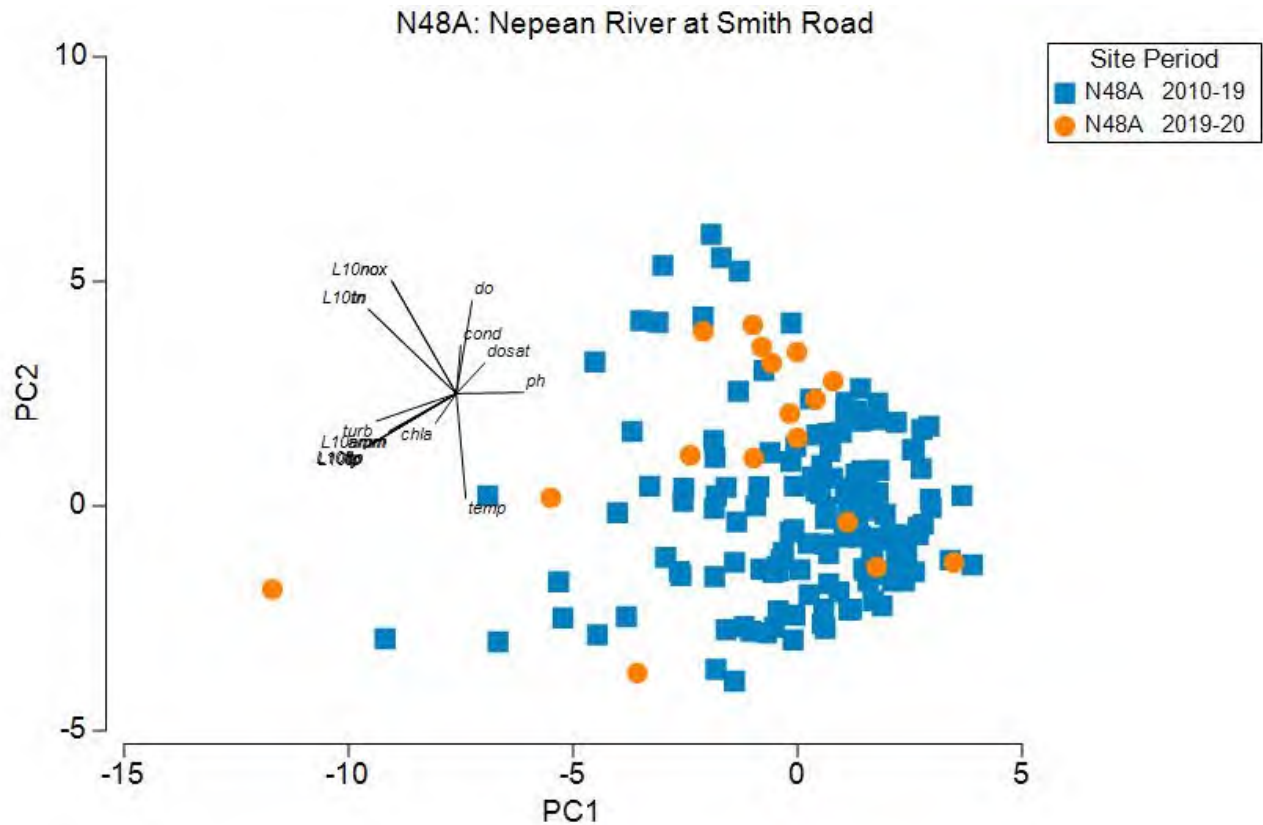
N51: Nepean River opposite Fitzgeralds Creek



N51: Nepean River opposite Fitzgeralds Creek

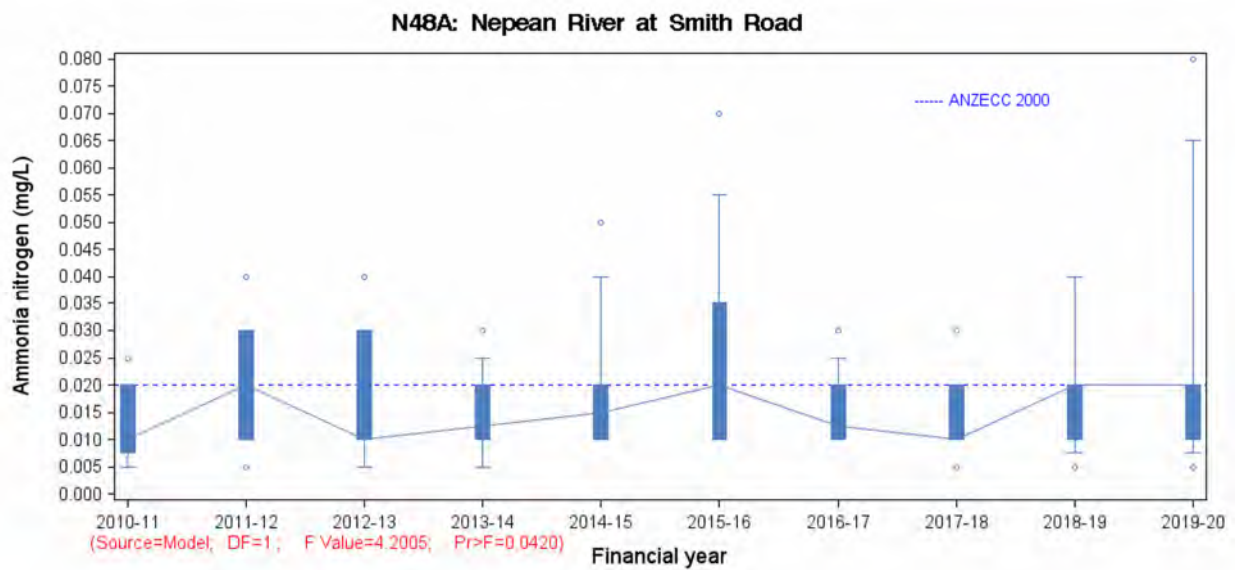


N48A: Nepean River at Smith Road

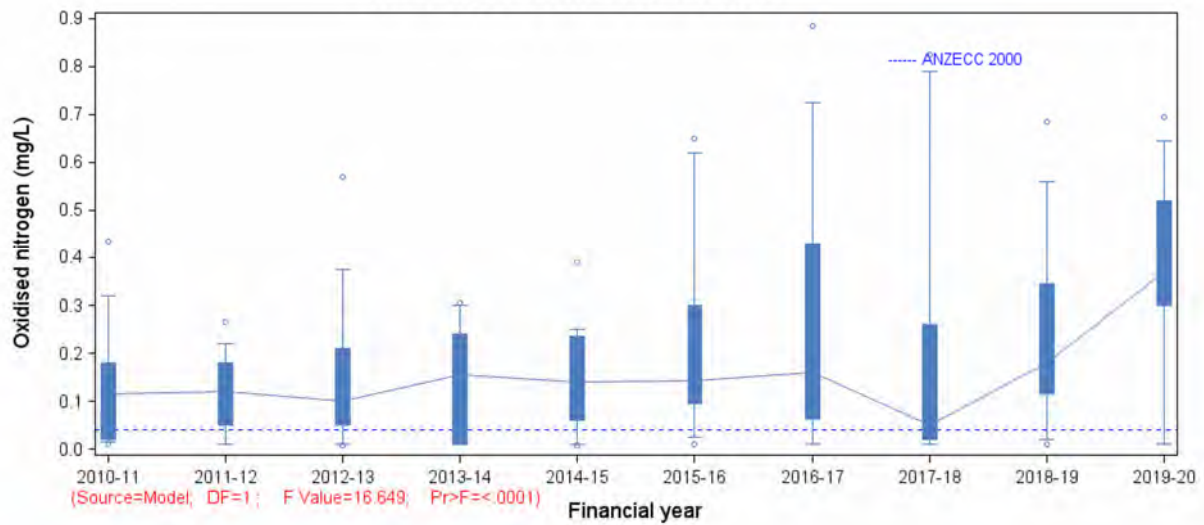


The ordination plot from Principal Components Analysis suggested water quality of the Nepean River at Smith Road in 2019-20 was similar to that recorded in the period 2010 to 2019.

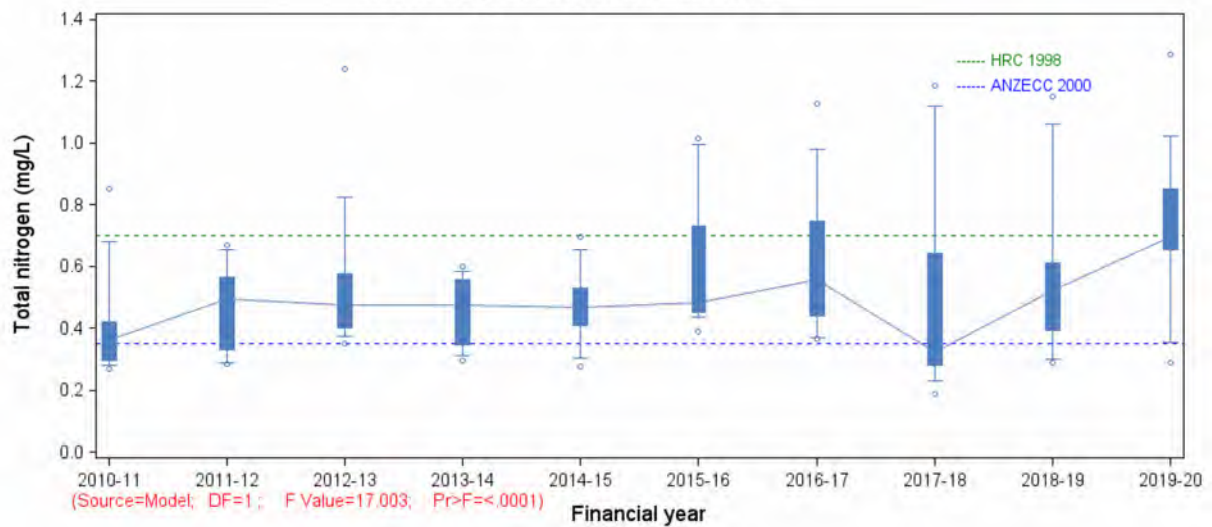
Nutrients, chlorophyll-a and algae



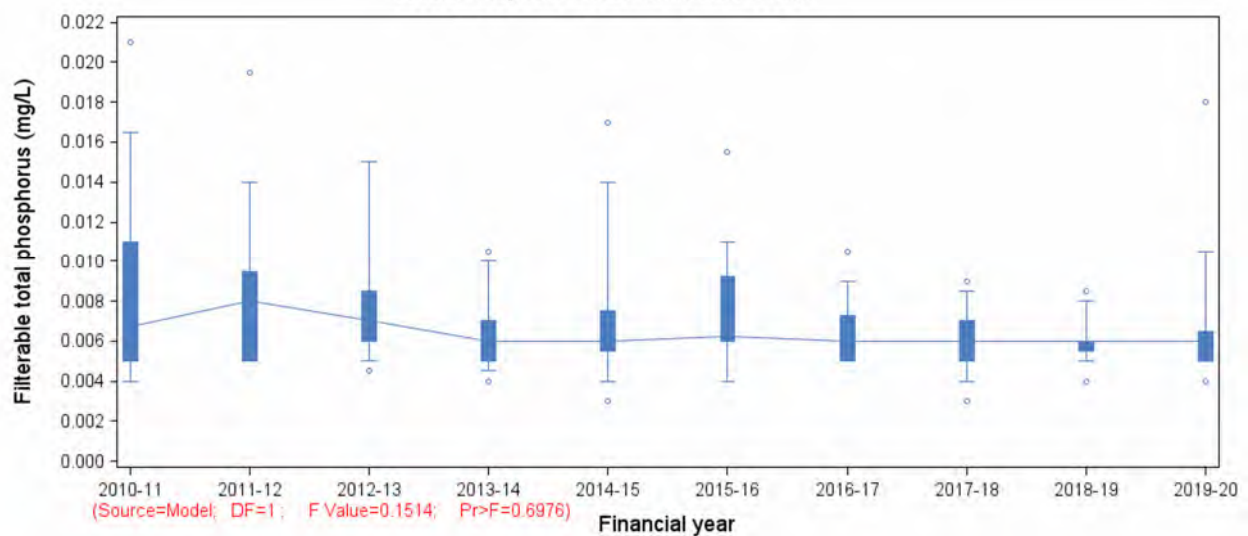
N48A: Nepean River at Smith Road



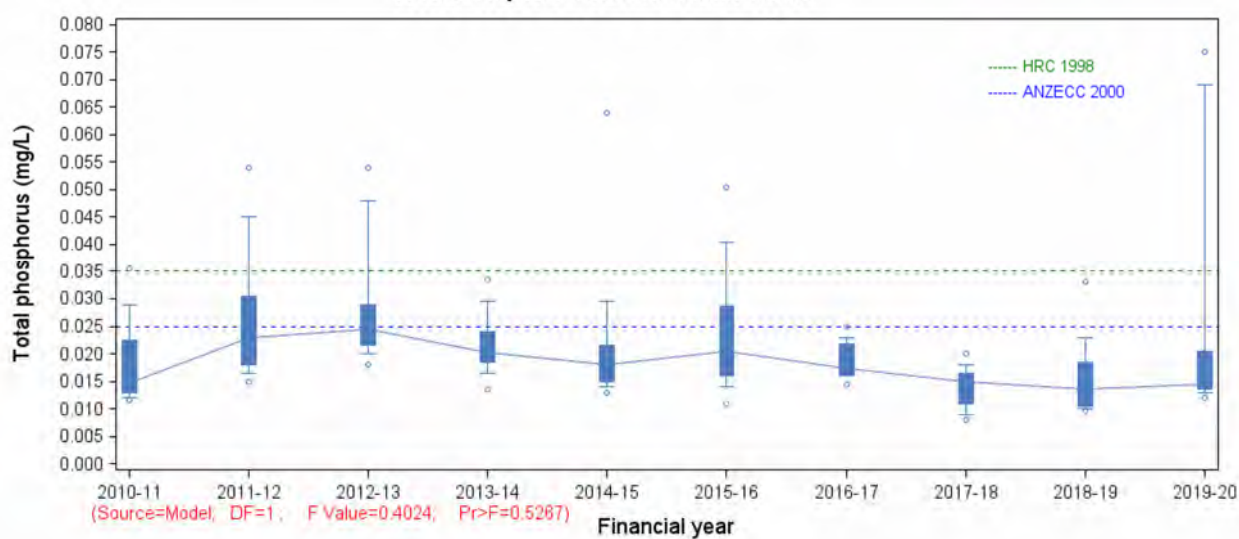
N48A: Nepean River at Smith Road



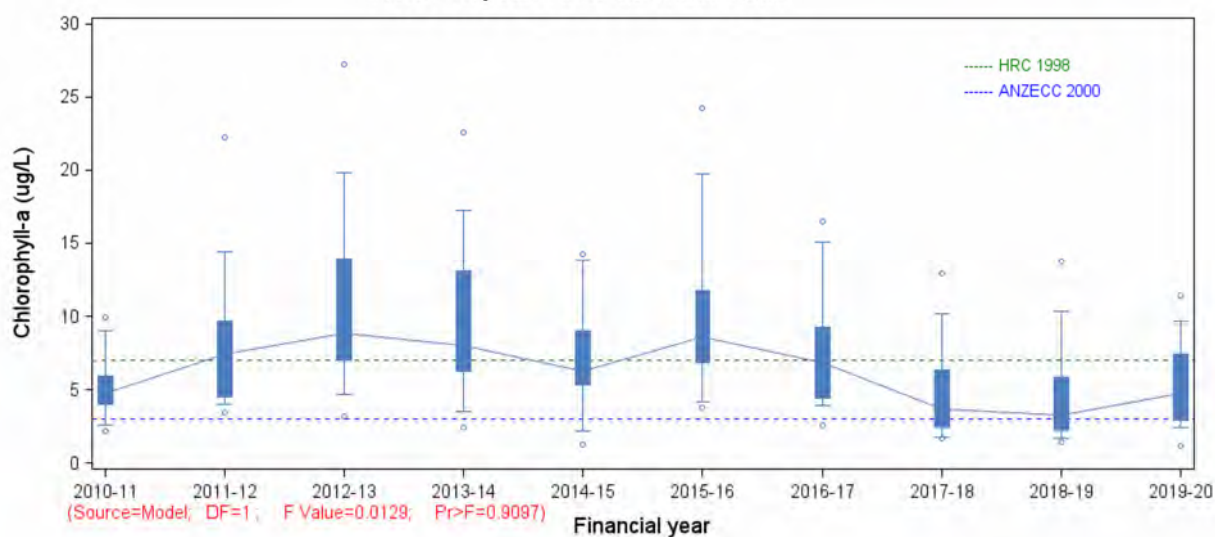
N48A: Nepean River at Smith Road



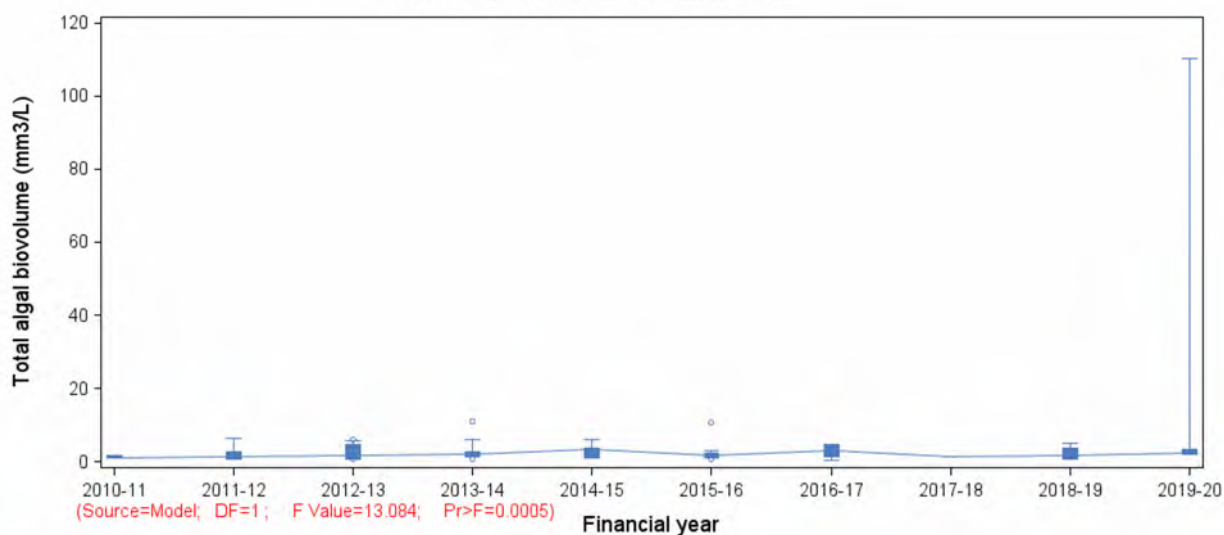
N48A: Nepean River at Smith Road



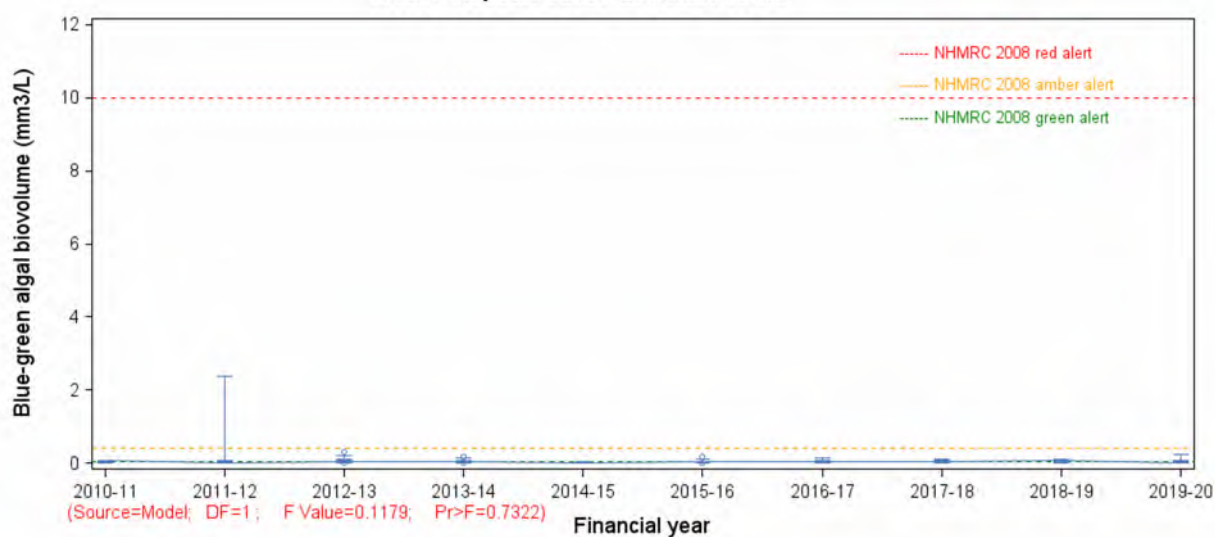
N48A: Nepean River at Smith Road



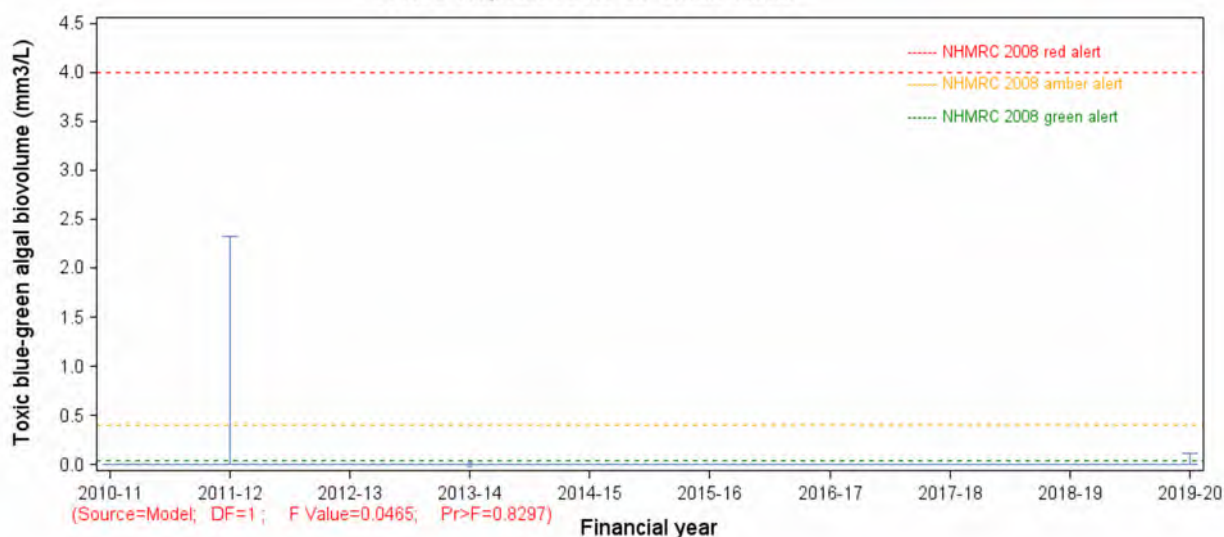
N48A: Nepean River at Smith Road



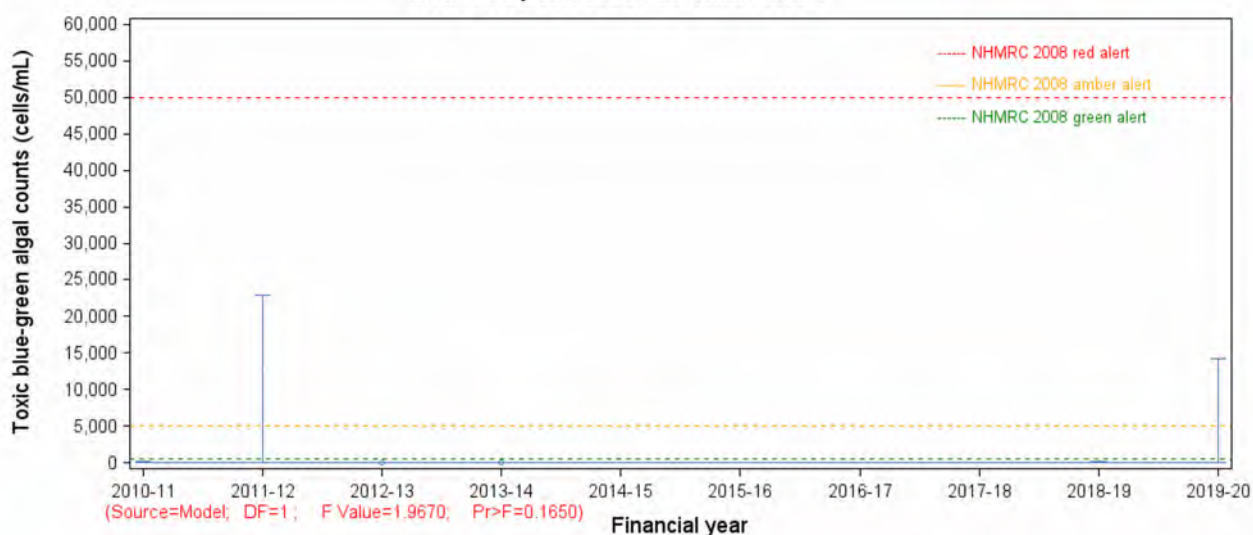
N48A: Nepean River at Smith Road



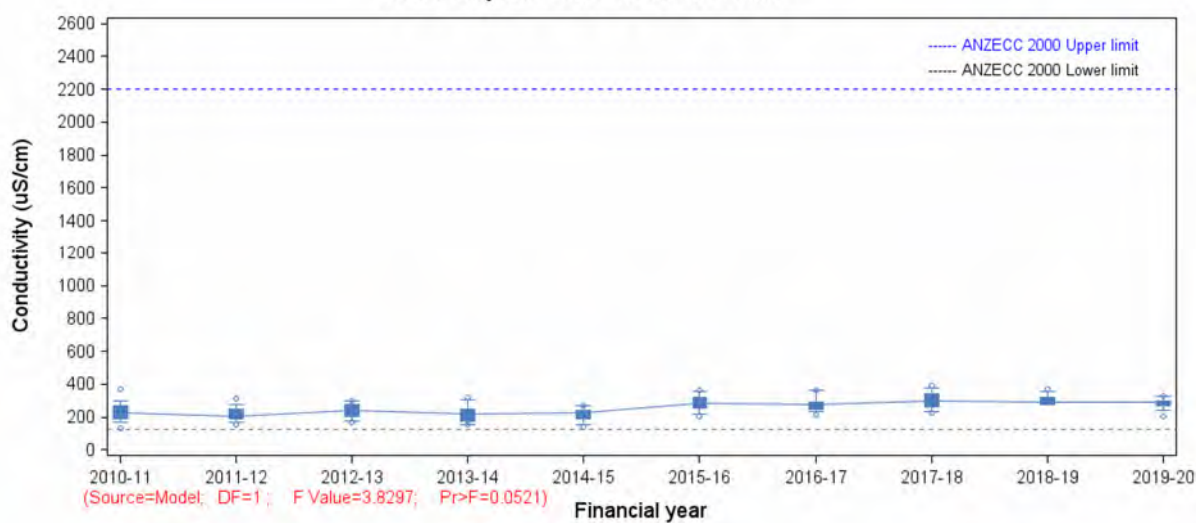
N48A: Nepean River at Smith Road



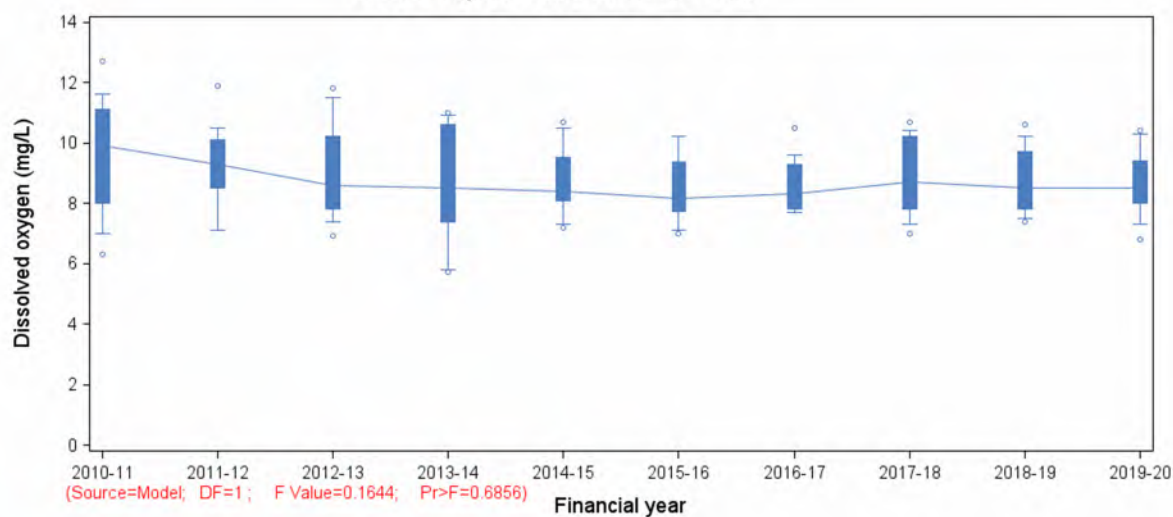
N48A: Nepean River at Smith Road



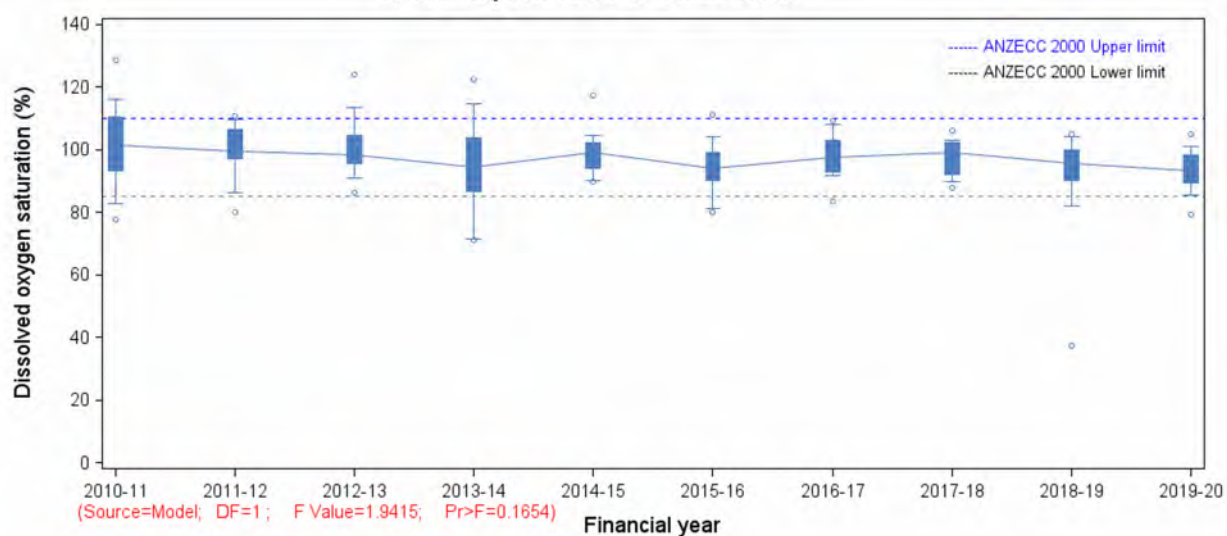
N48A: Nepean River at Smith Road



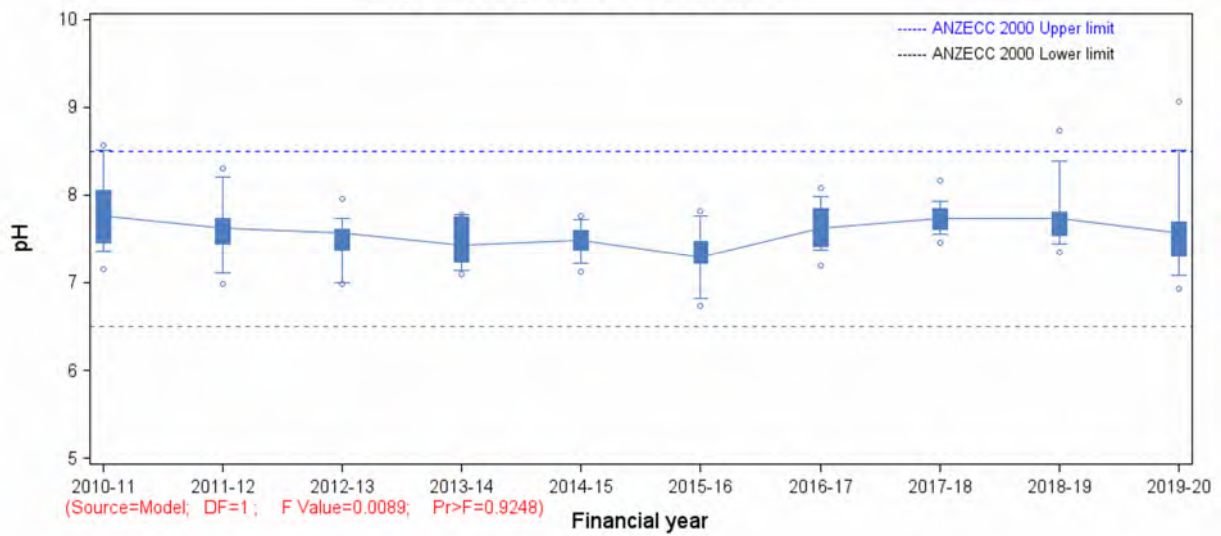
N48A: Nepean River at Smith Road



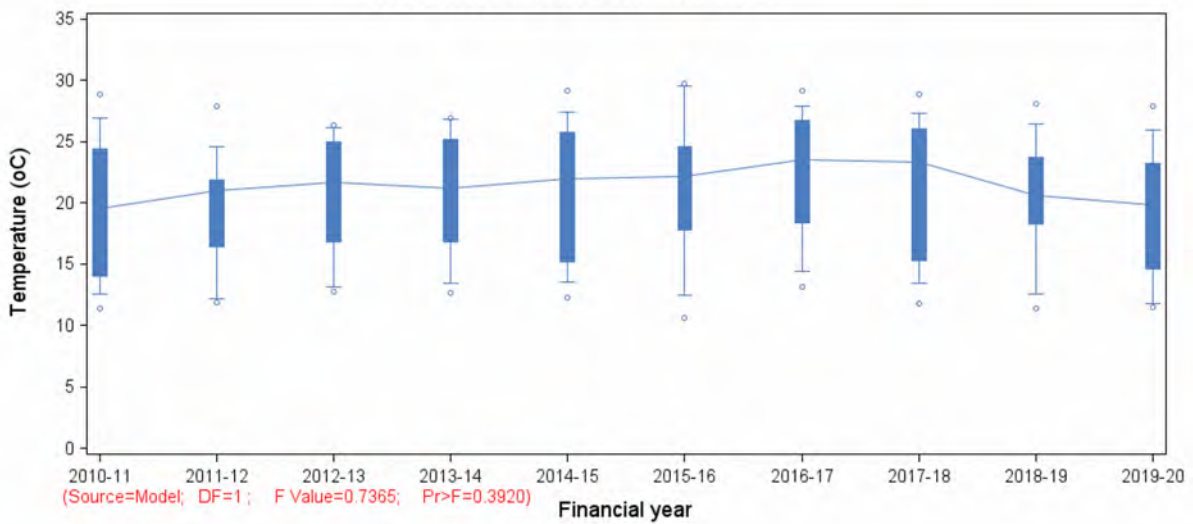
N48A: Nepean River at Smith Road



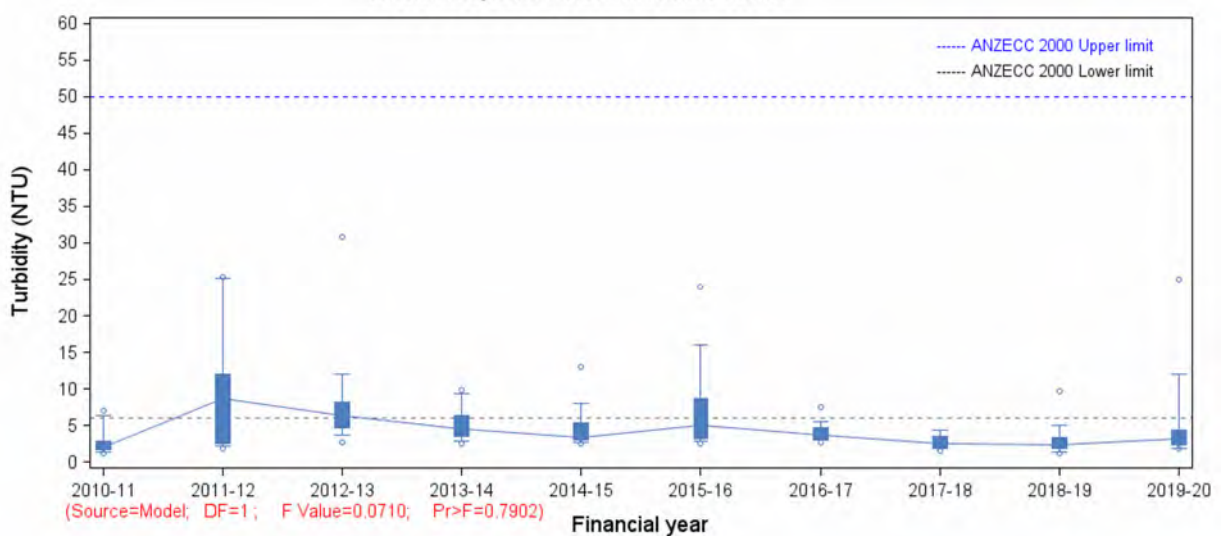
N48A: Nepean River at Smith Road



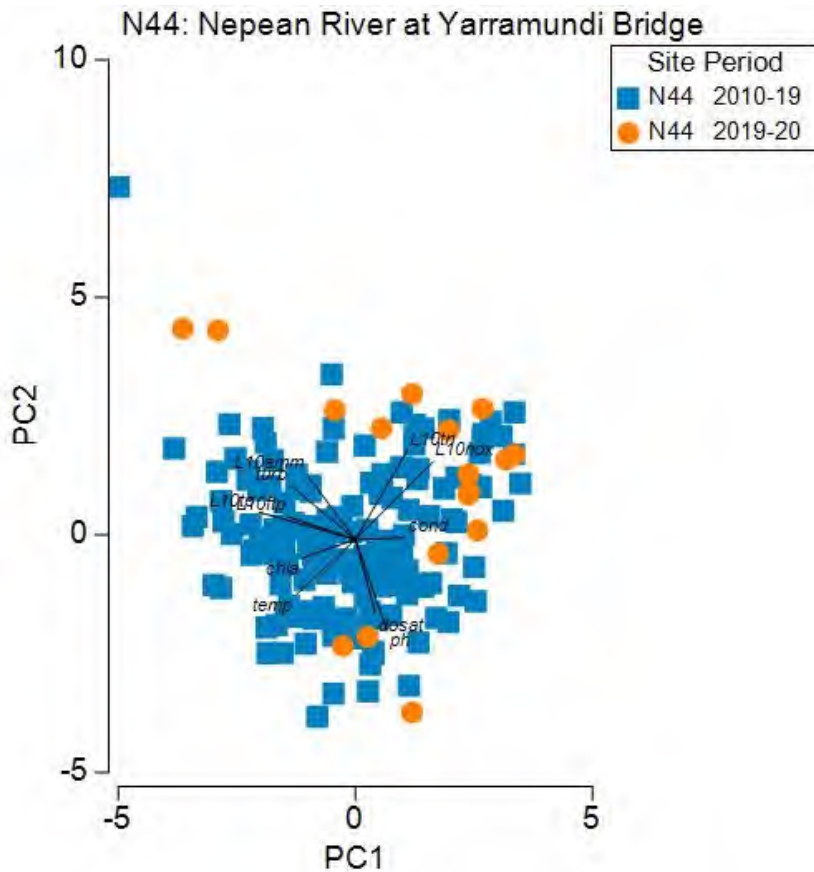
N48A: Nepean River at Smith Road



N48A: Nepean River at Smith Road

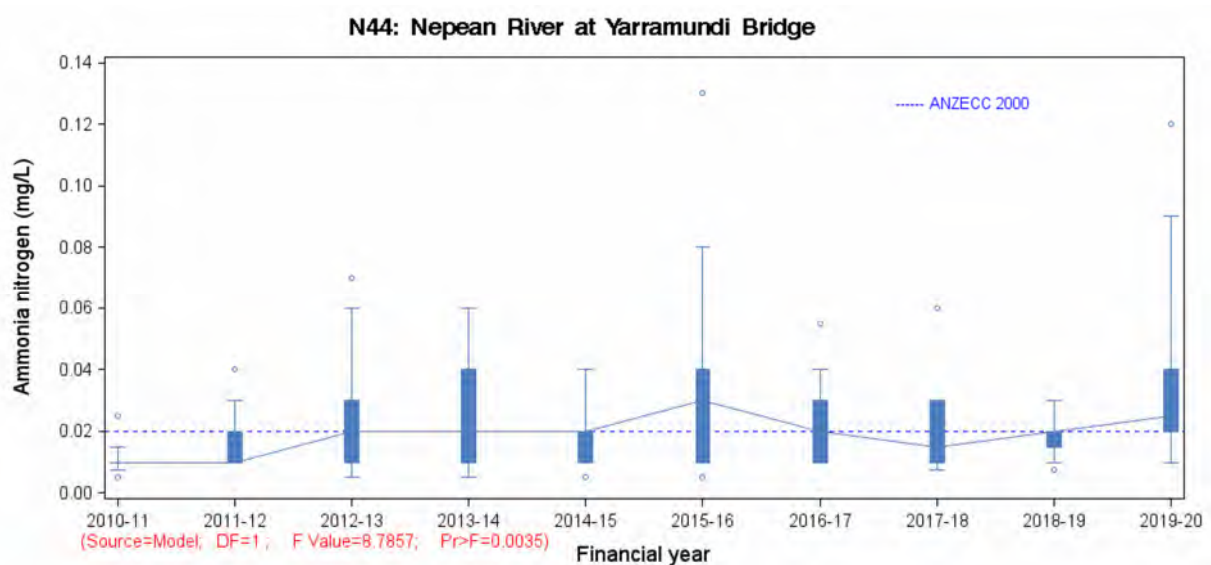


N44: Nepean River at Yarramundi Bridge

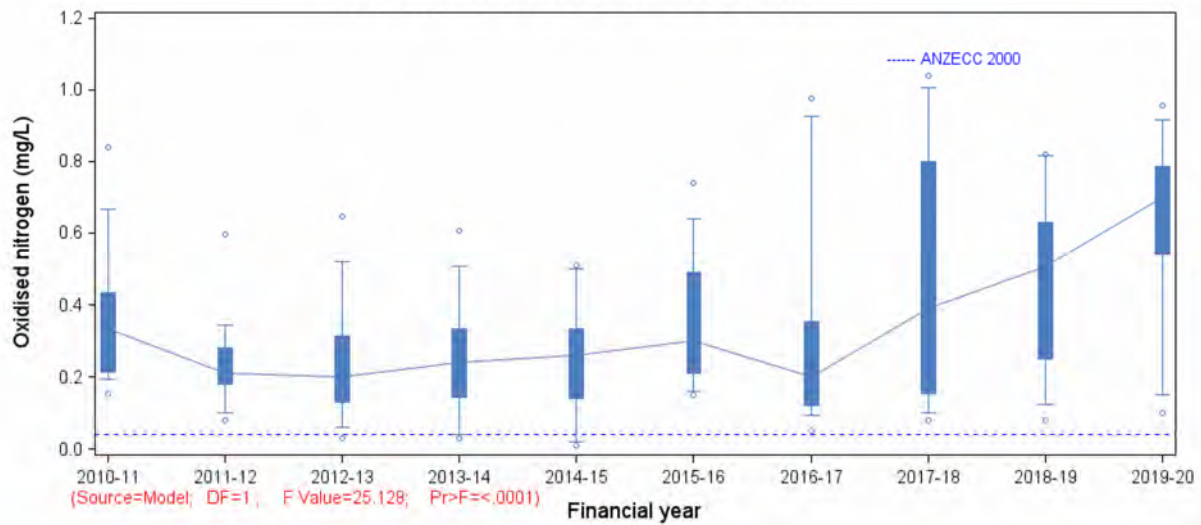


The ordination plot from Principal Components Analysis suggested water quality of the Nepean River at Yarramundi Bridge in 2019-20 was similar to that recorded in the period 2010 to 2019.

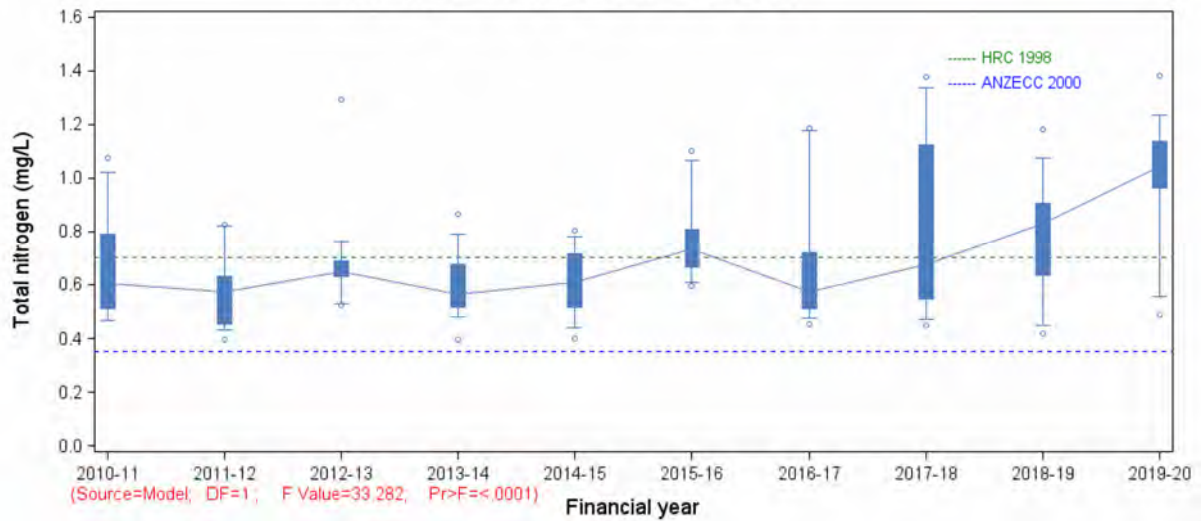
Nutrients, chlorophyll-a and algae



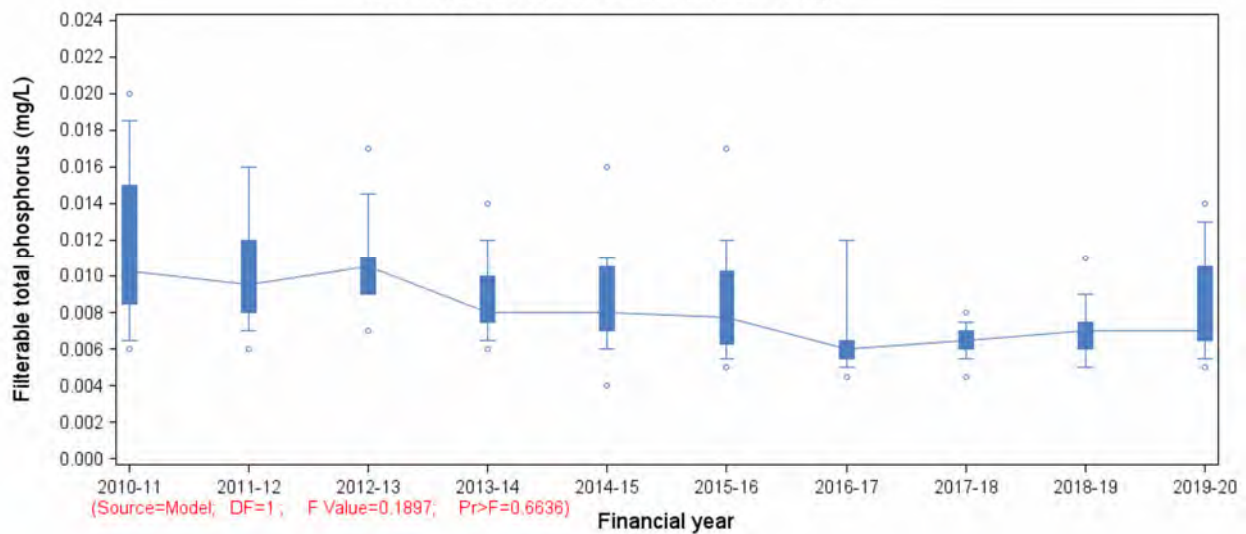
N44: Nepean River at Yarramundi Bridge



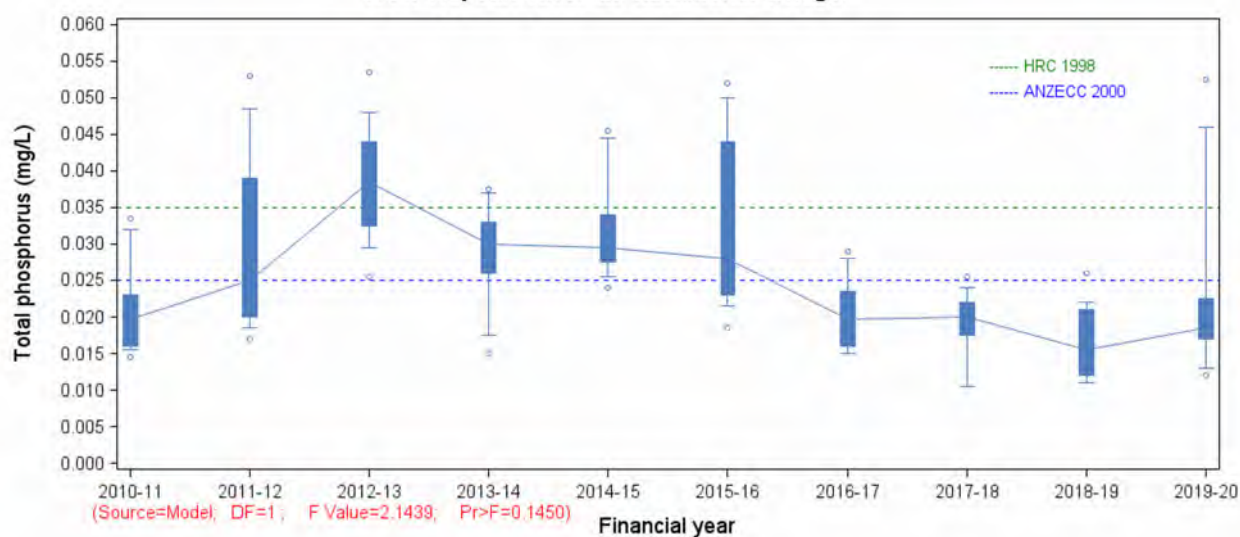
N44: Nepean River at Yarramundi Bridge



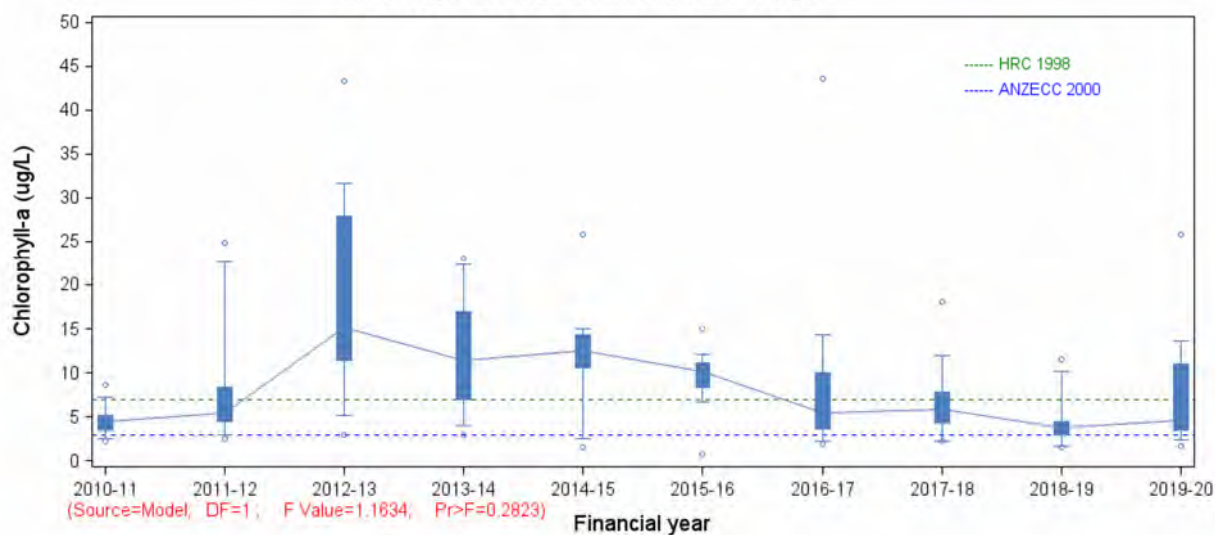
N44: Nepean River at Yarramundi Bridge



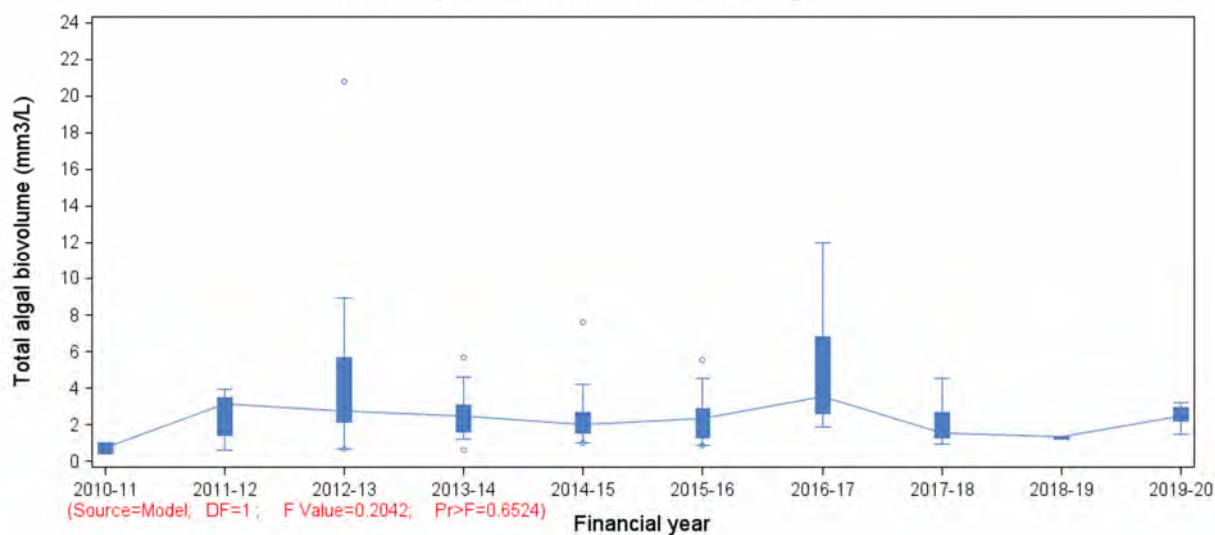
N44: Nepean River at Yarramundi Bridge



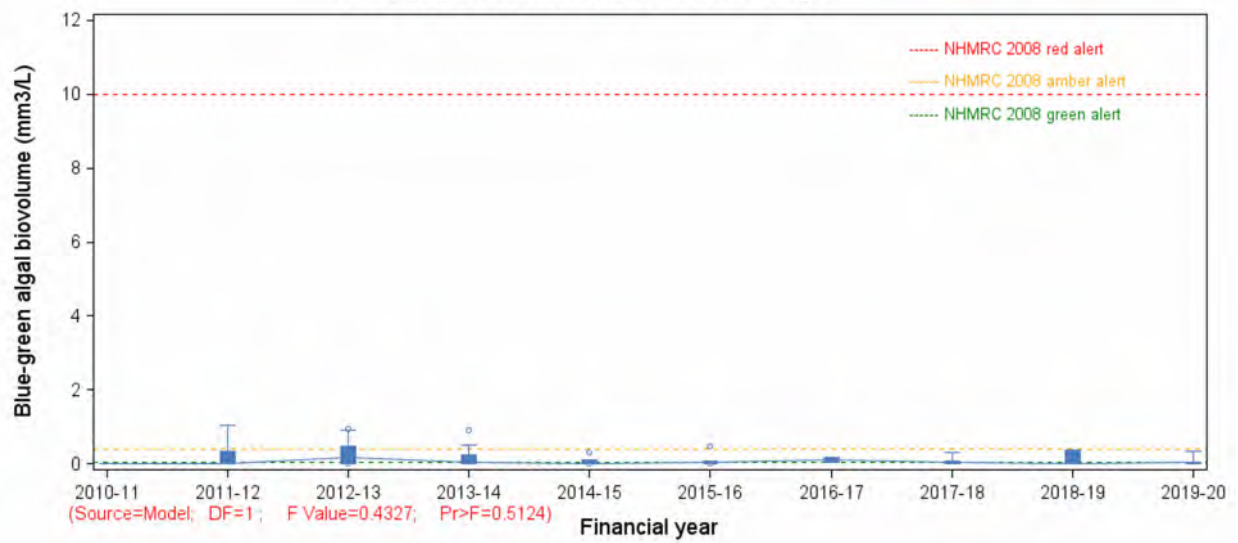
N44: Nepean River at Yarramundi Bridge



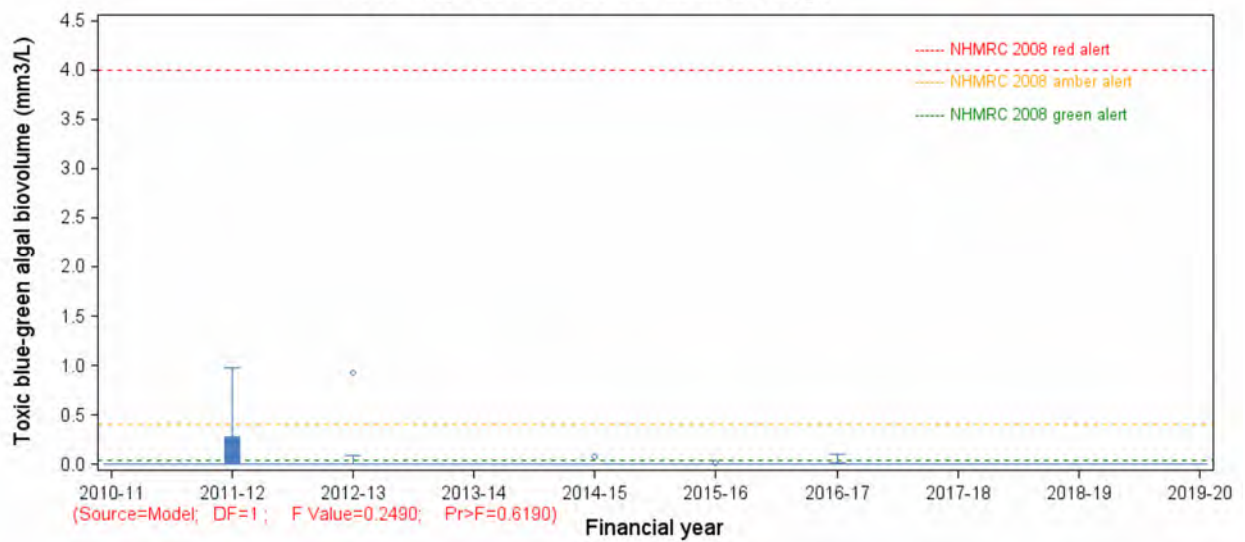
N44: Nepean River at Yarramundi Bridge



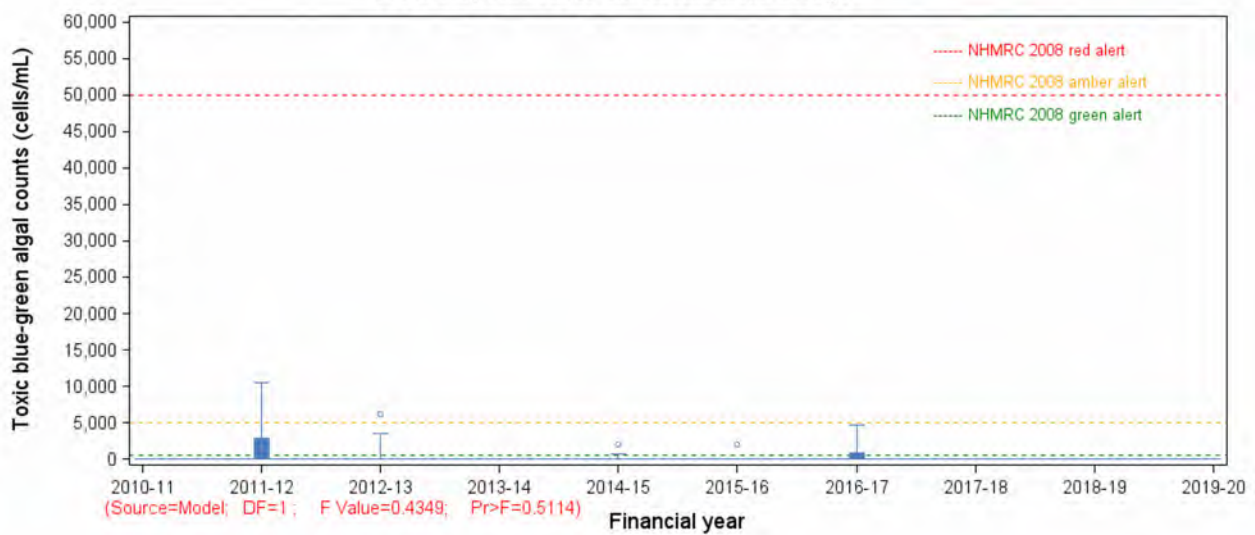
N44: Nepean River at Yarramundi Bridge



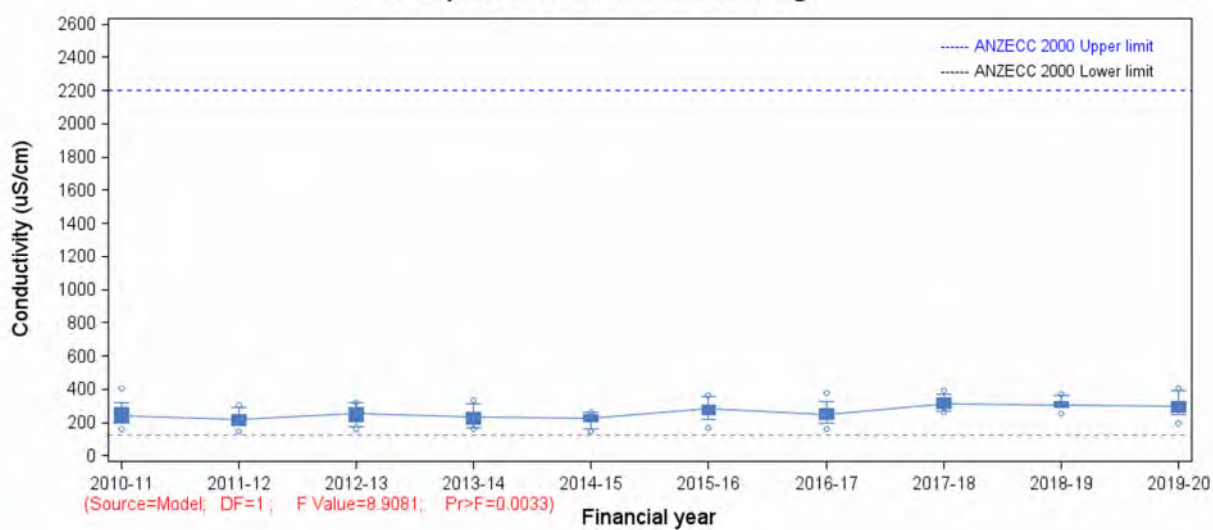
N44: Nepean River at Yarramundi Bridge



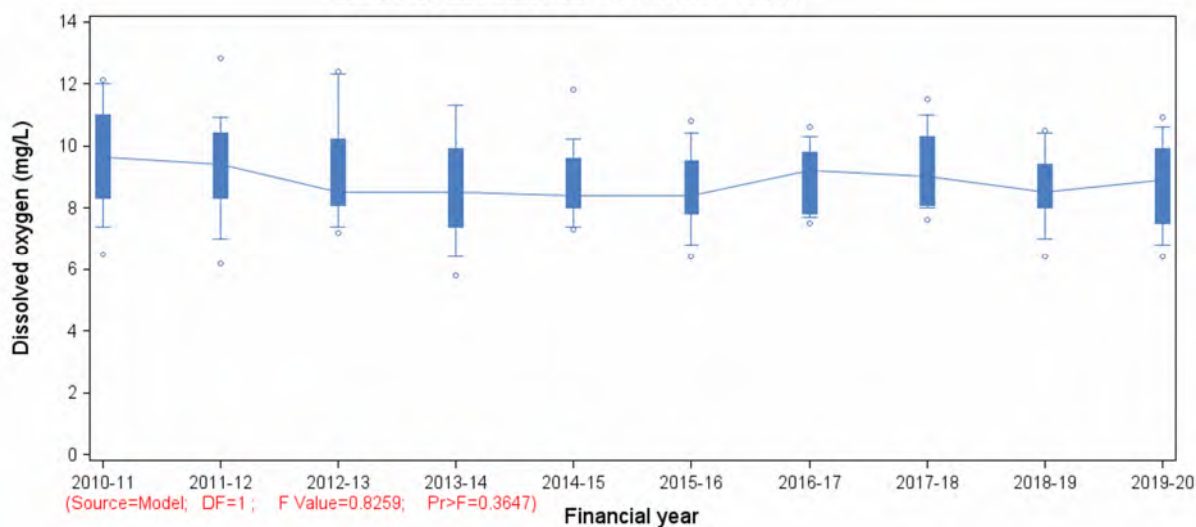
N44: Nepean River at Yarramundi Bridge



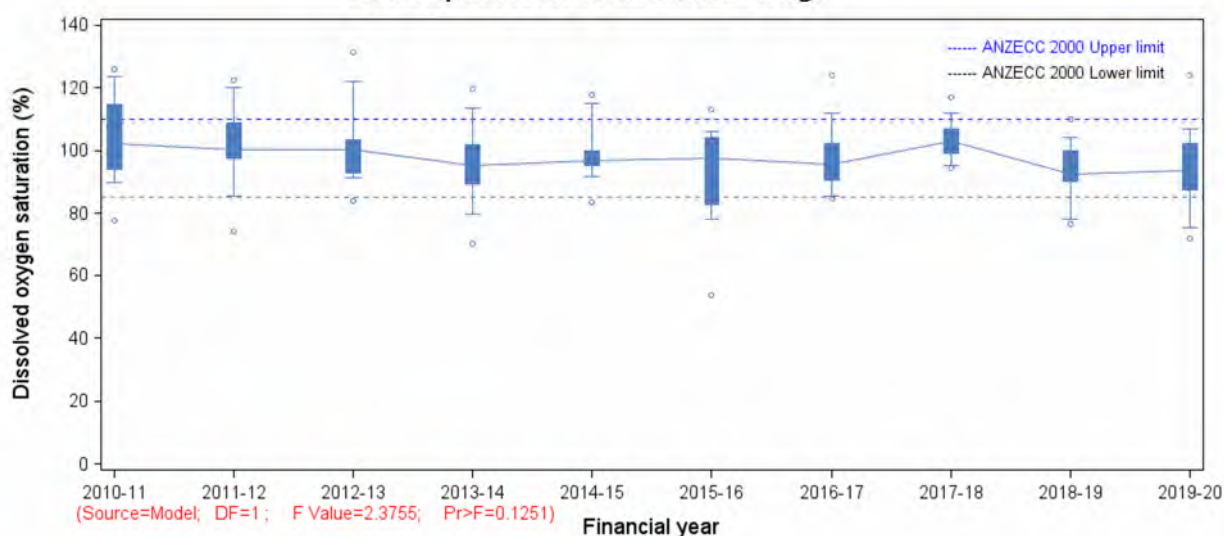
N44: Nepean River at Yarramundi Bridge



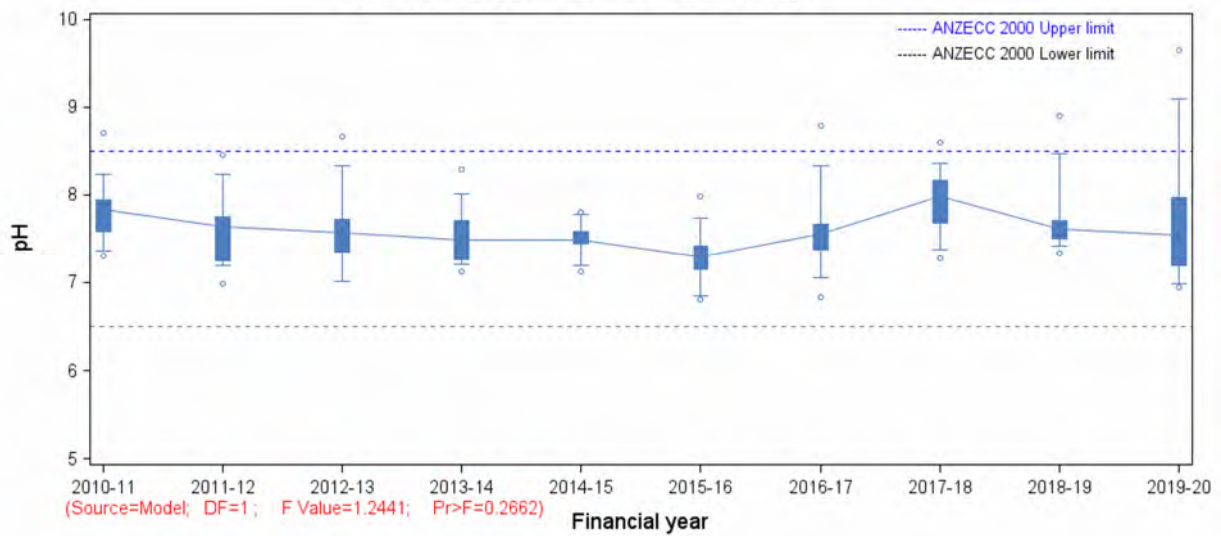
N44: Nepean River at Yarramundi Bridge



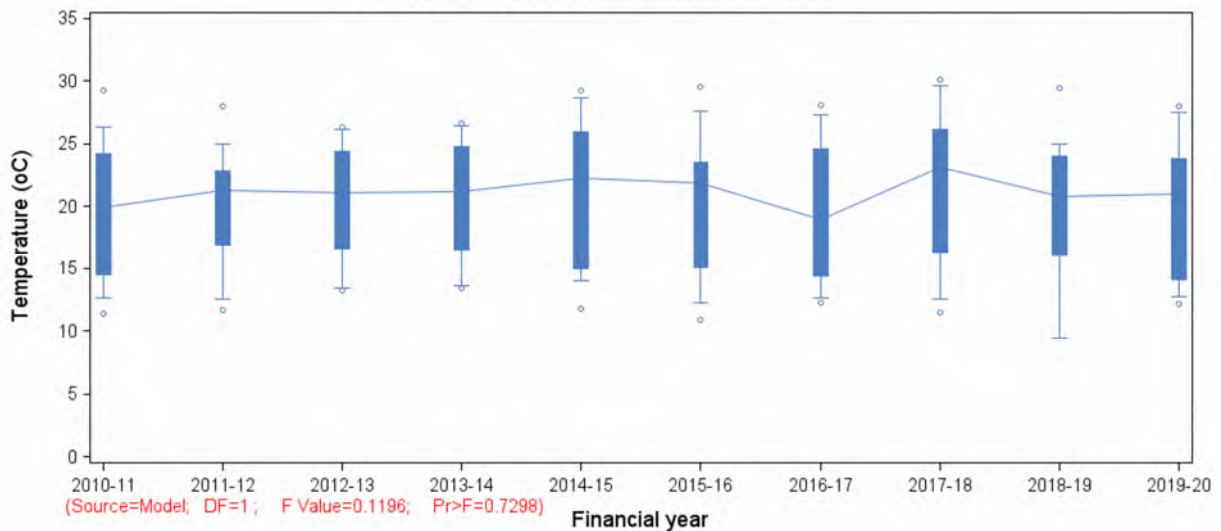
N44: Nepean River at Yarramundi Bridge



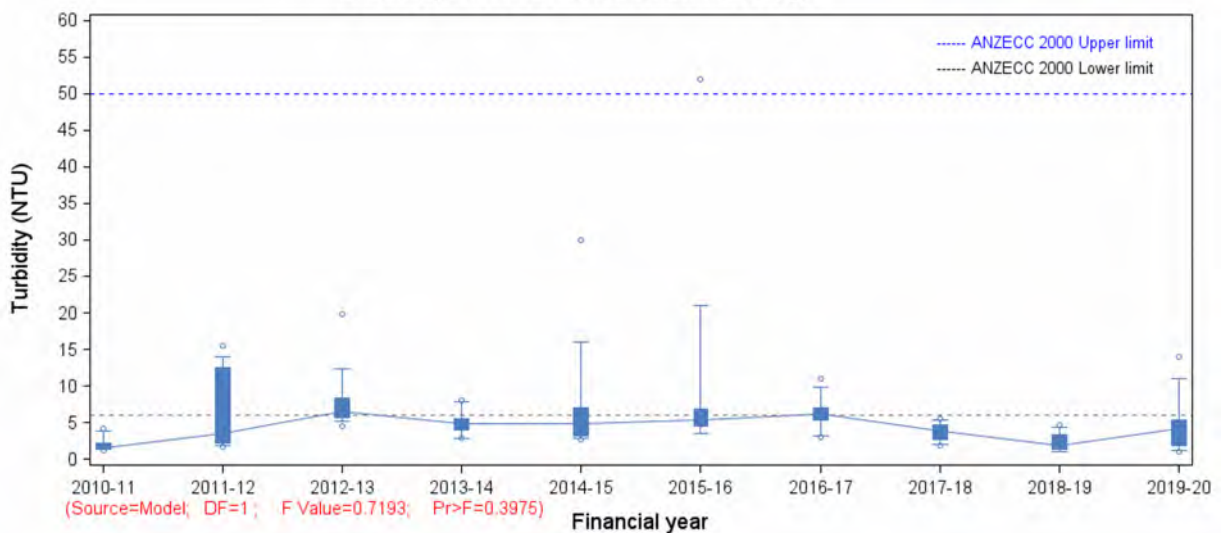
N44: Nepean River at Yarramundi Bridge



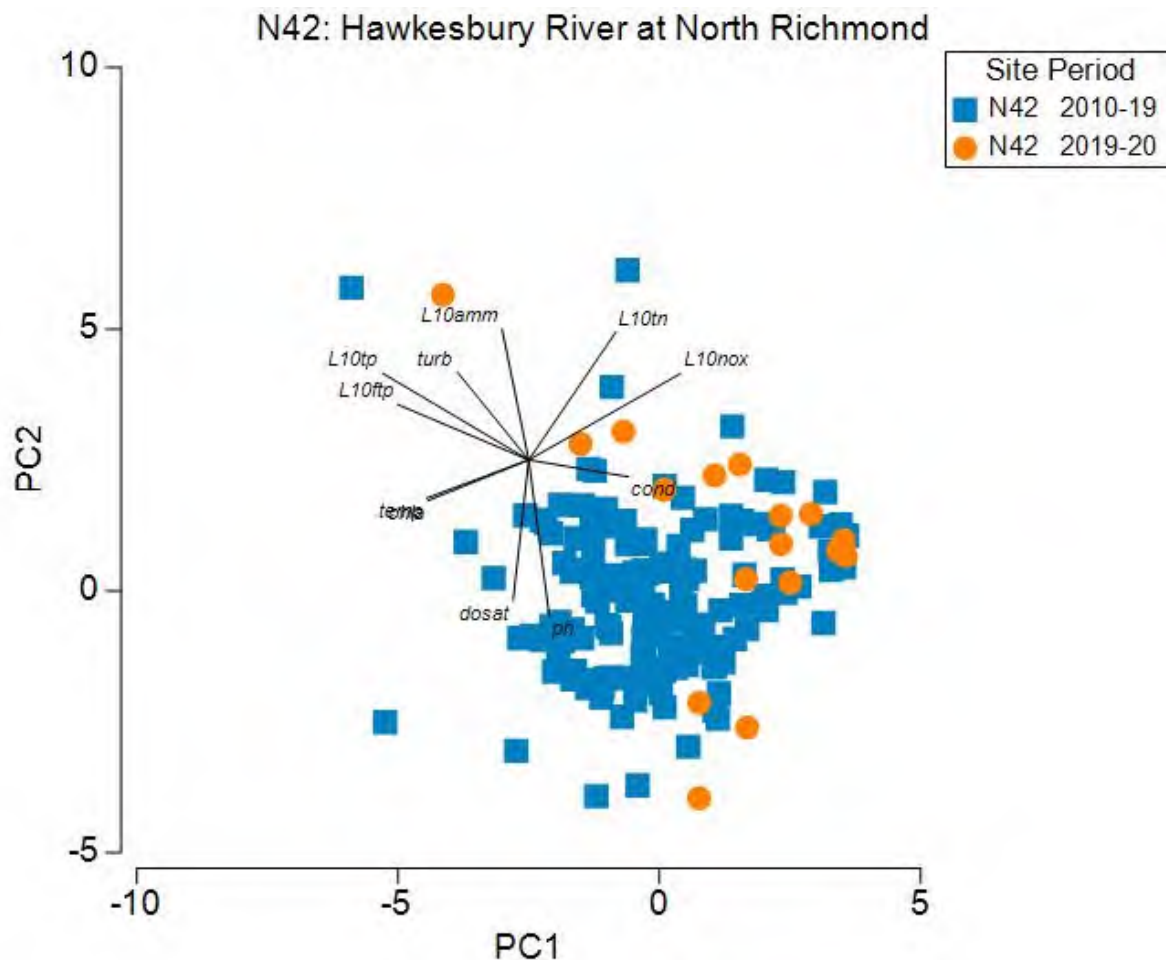
N44: Nepean River at Yarramundi Bridge



N44: Nepean River at Yarramundi Bridge

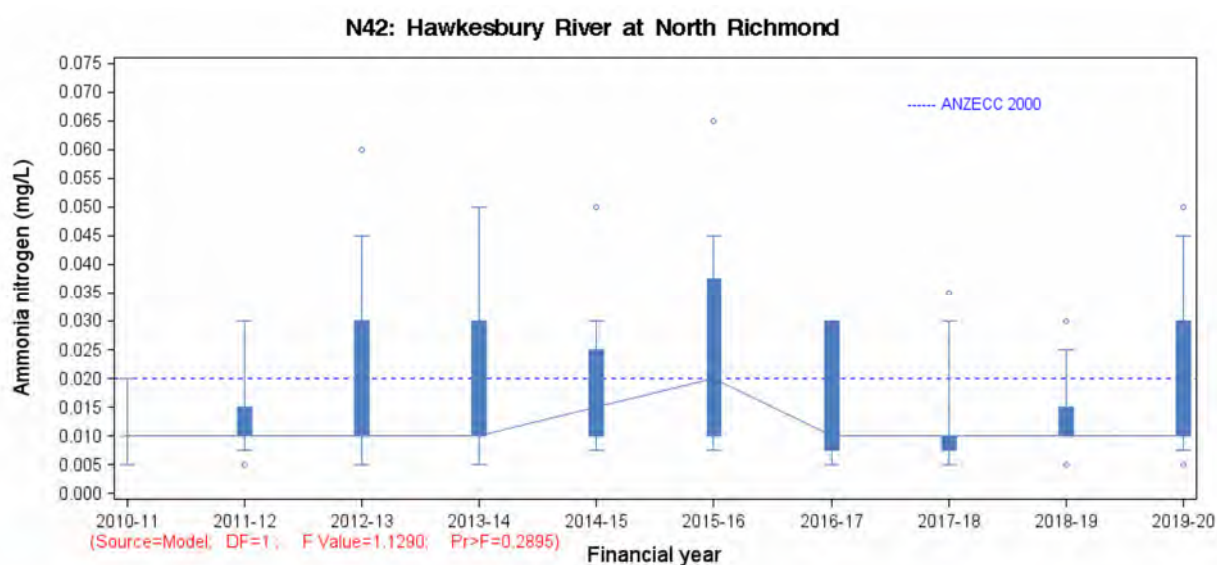


N42: Hawkesbury River at North Richmond

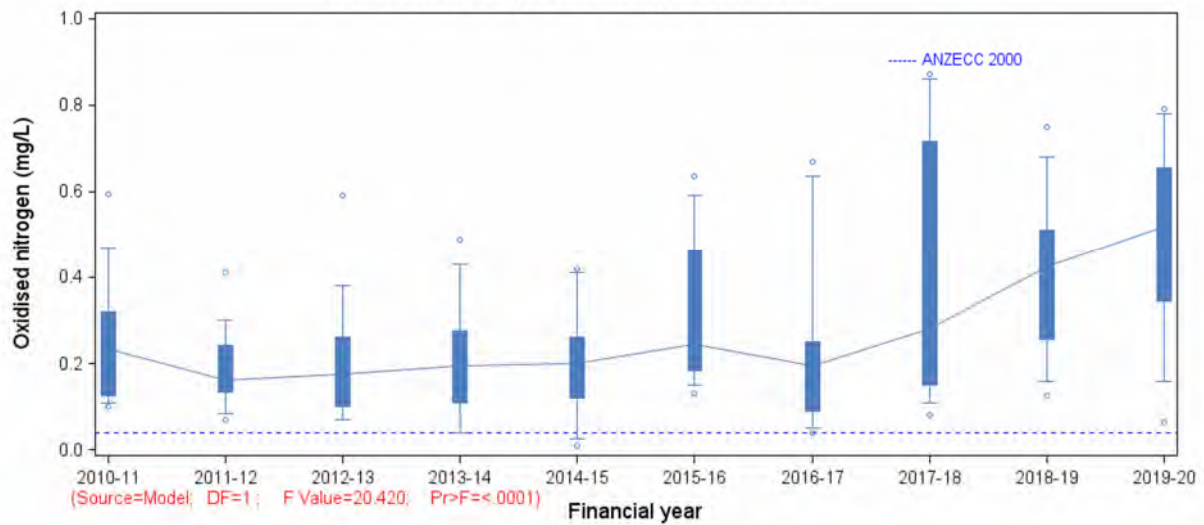


The ordination plot from Principal Components Analysis suggested water quality of the Hawkesbury River at North Richmond in 2019-20 was similar to that recorded in the period 2010 to 2019.

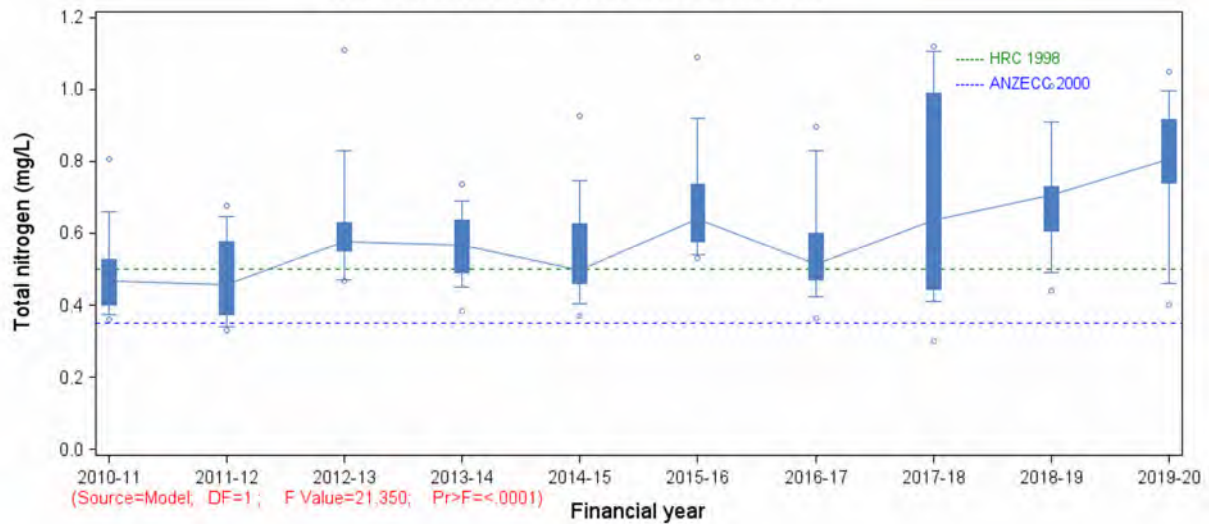
Nutrients, chlorophyll-a and algae



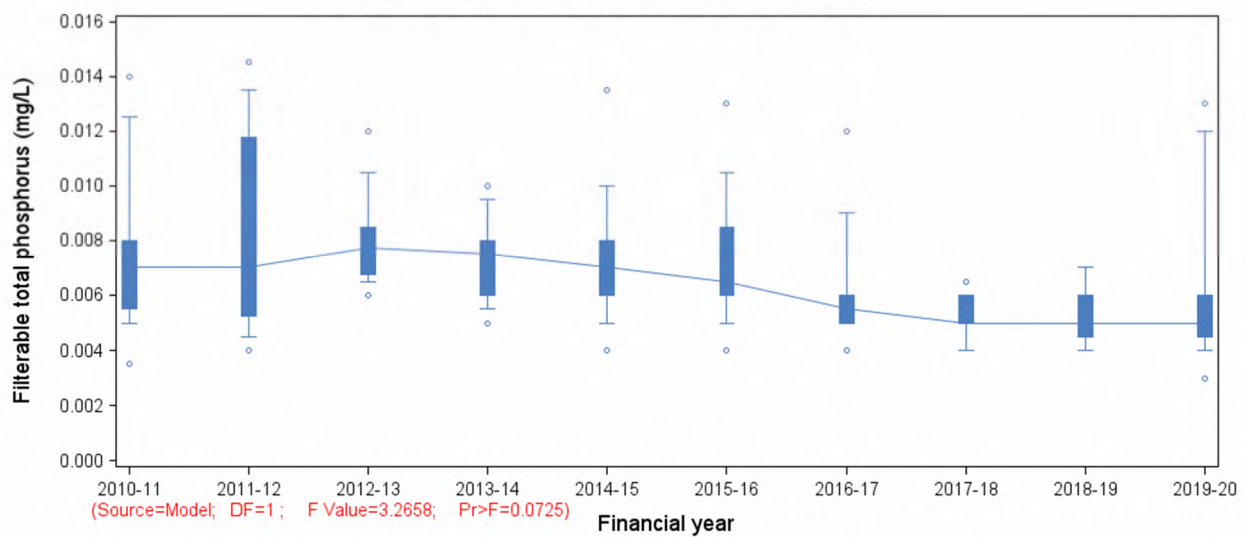
N42: Hawkesbury River at North Richmond



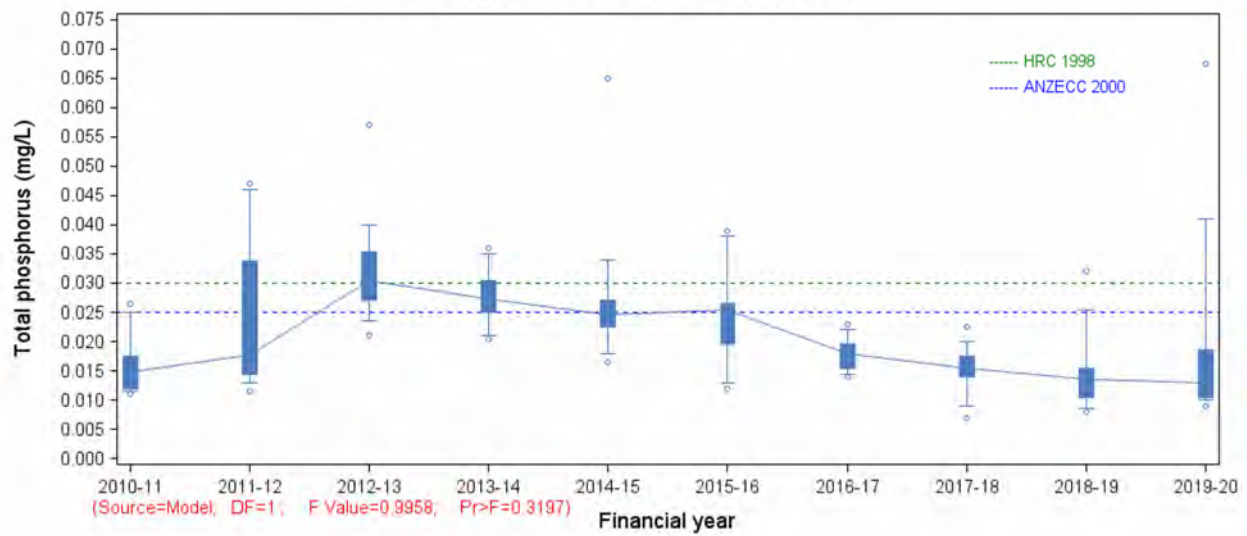
N42: Hawkesbury River at North Richmond



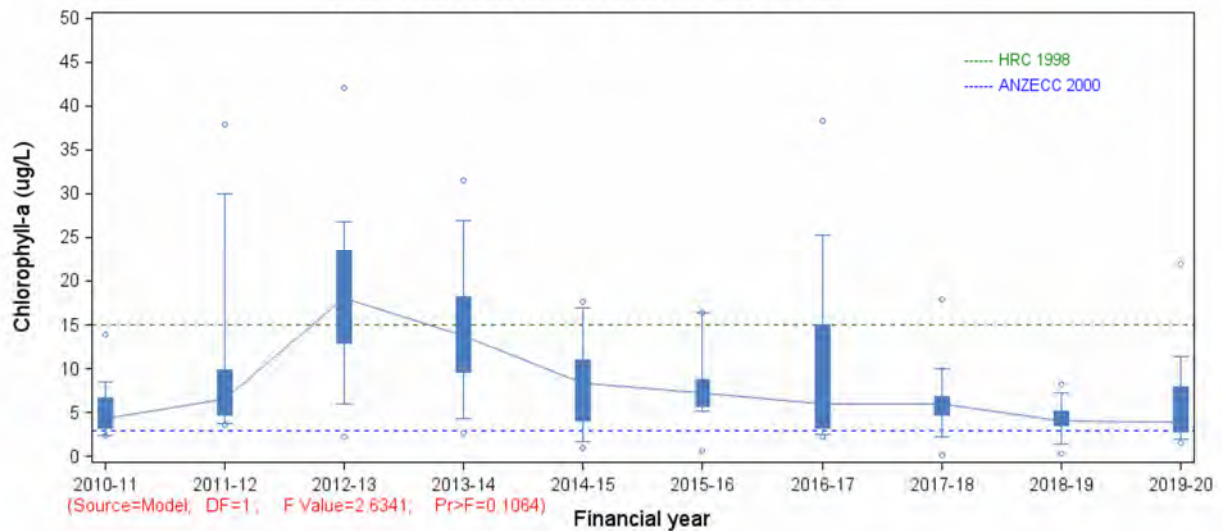
N42: Hawkesbury River at North Richmond



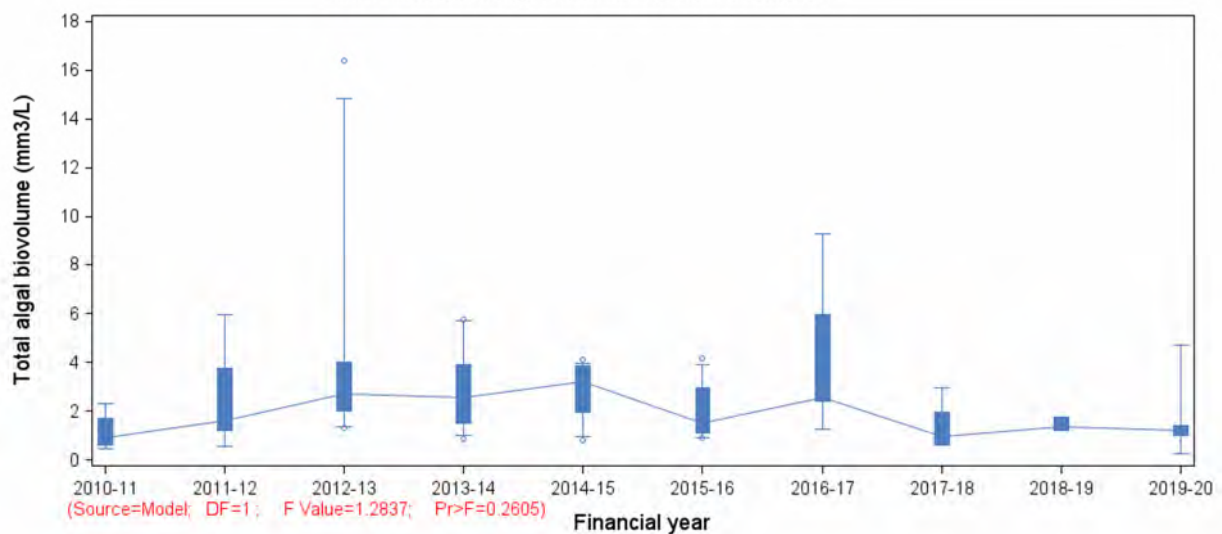
N42: Hawkesbury River at North Richmond



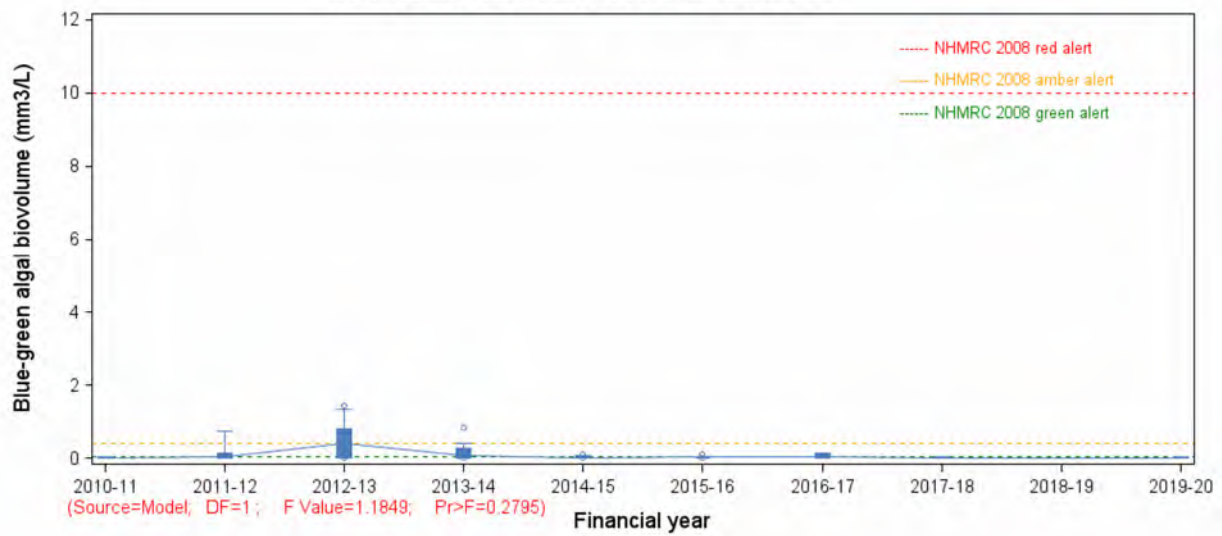
N42: Hawkesbury River at North Richmond



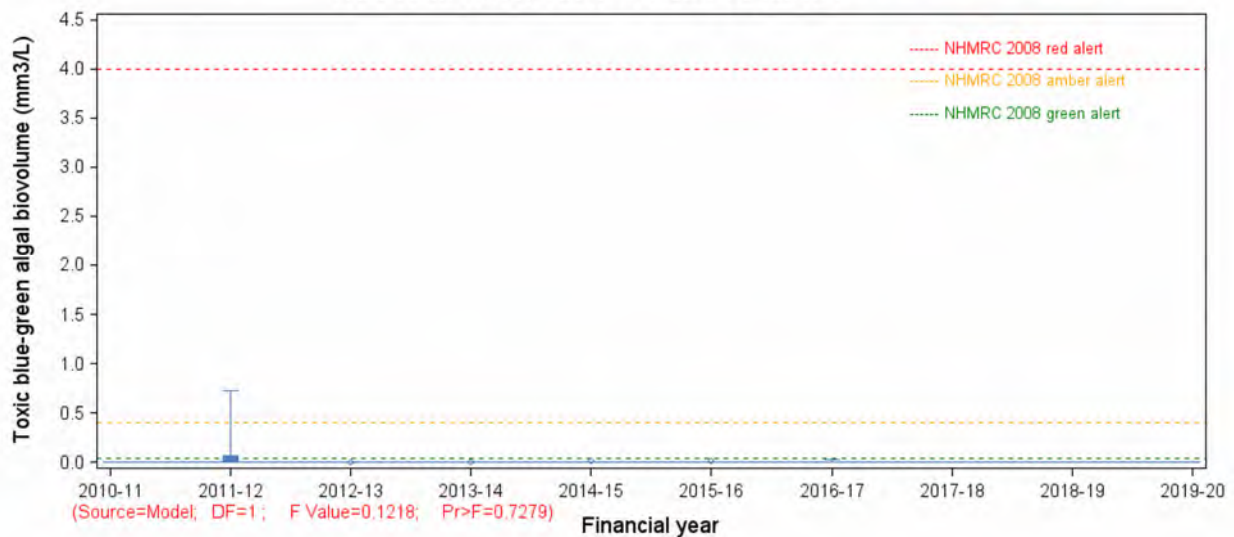
N42: Hawkesbury River at North Richmond



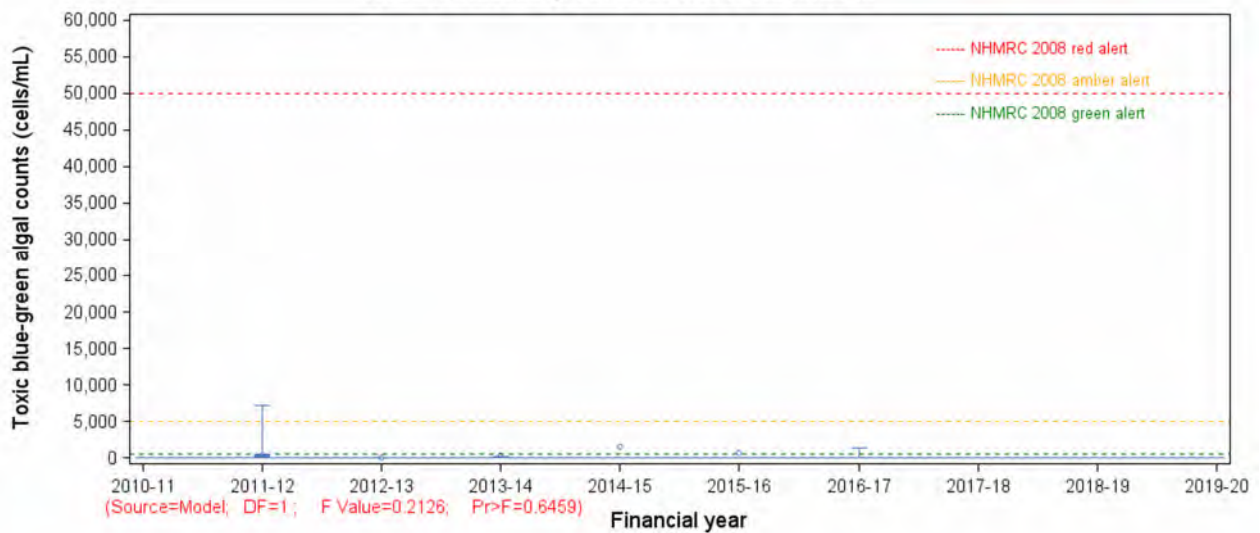
N42: Hawkesbury River at North Richmond



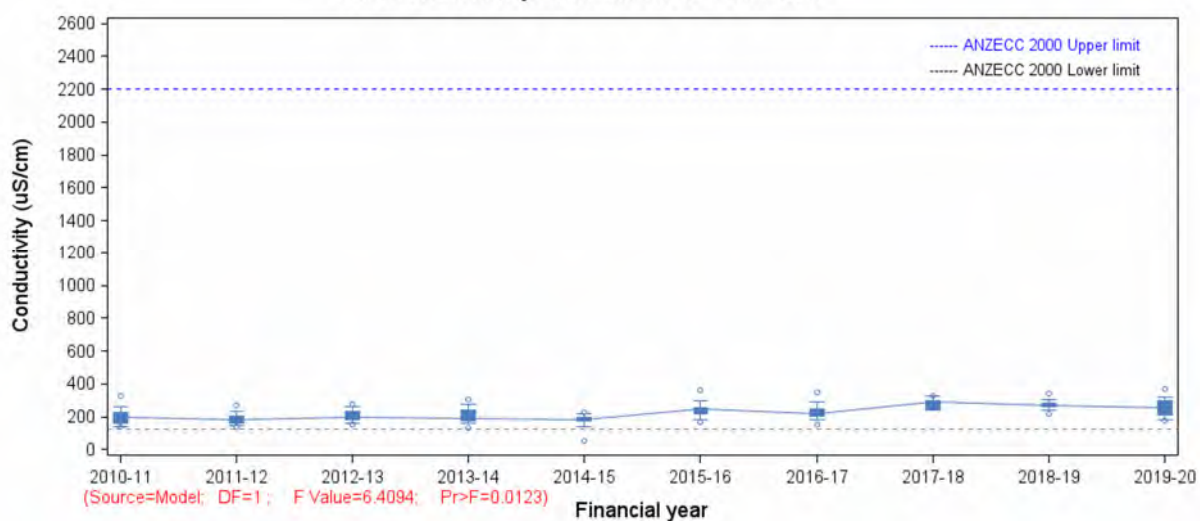
N42: Hawkesbury River at North Richmond



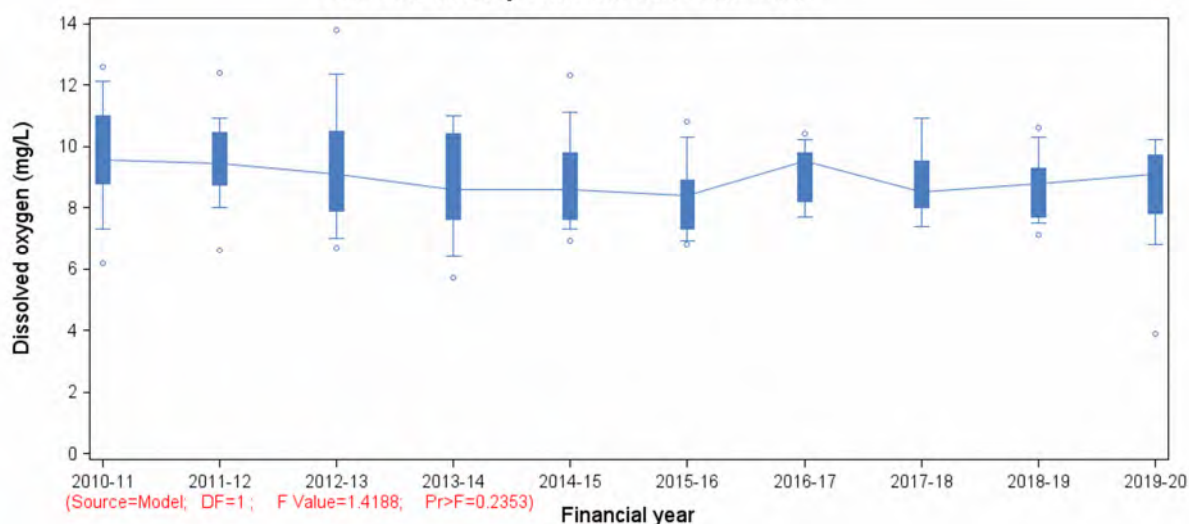
N42: Hawkesbury River at North Richmond



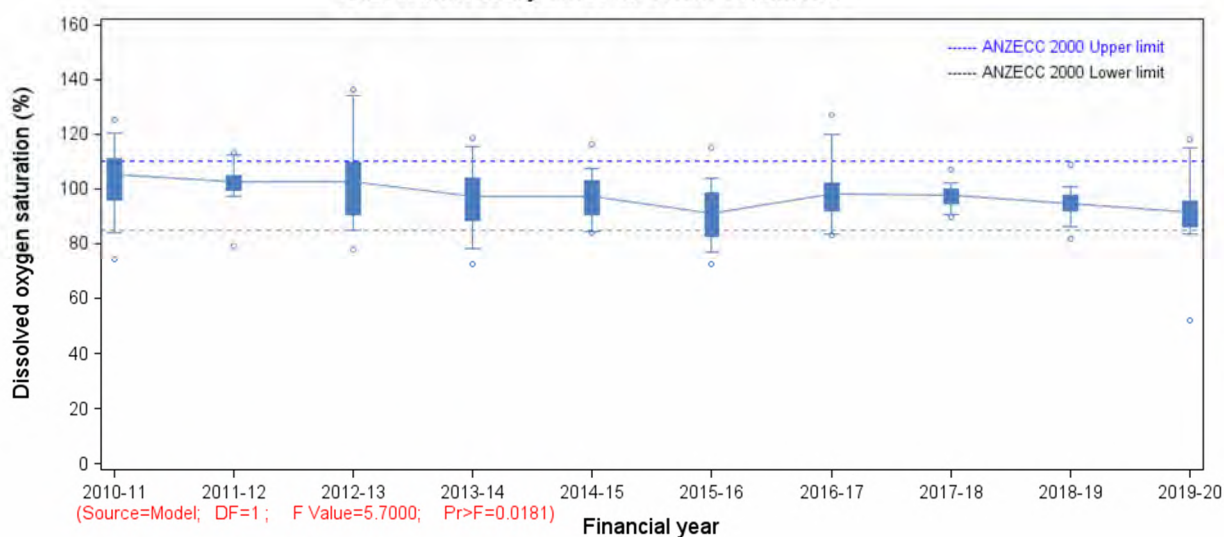
N42: Hawkesbury River at North Richmond



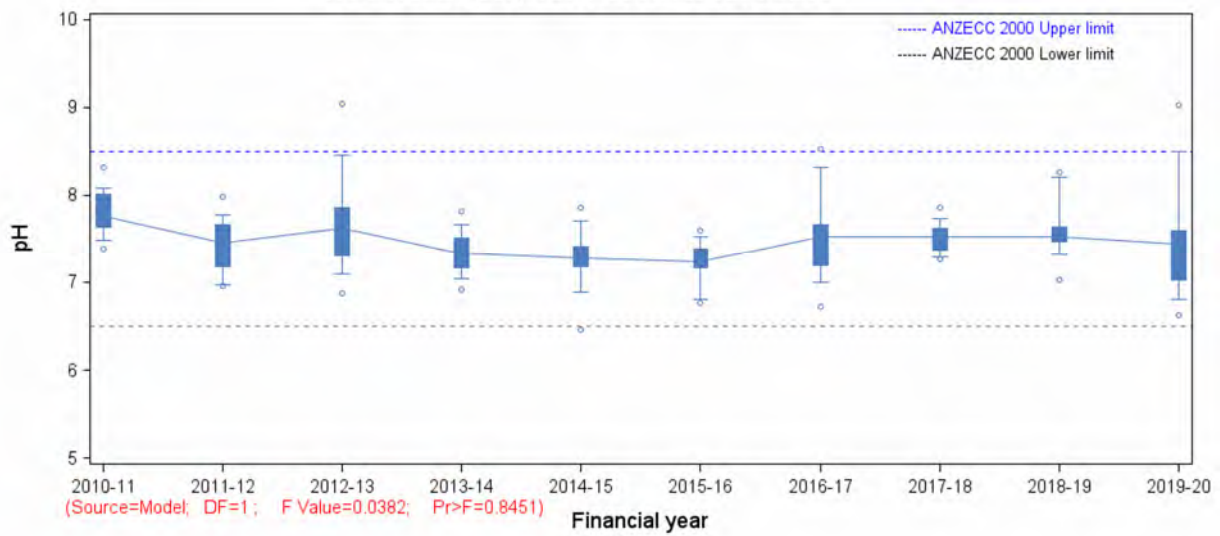
N42: Hawkesbury River at North Richmond



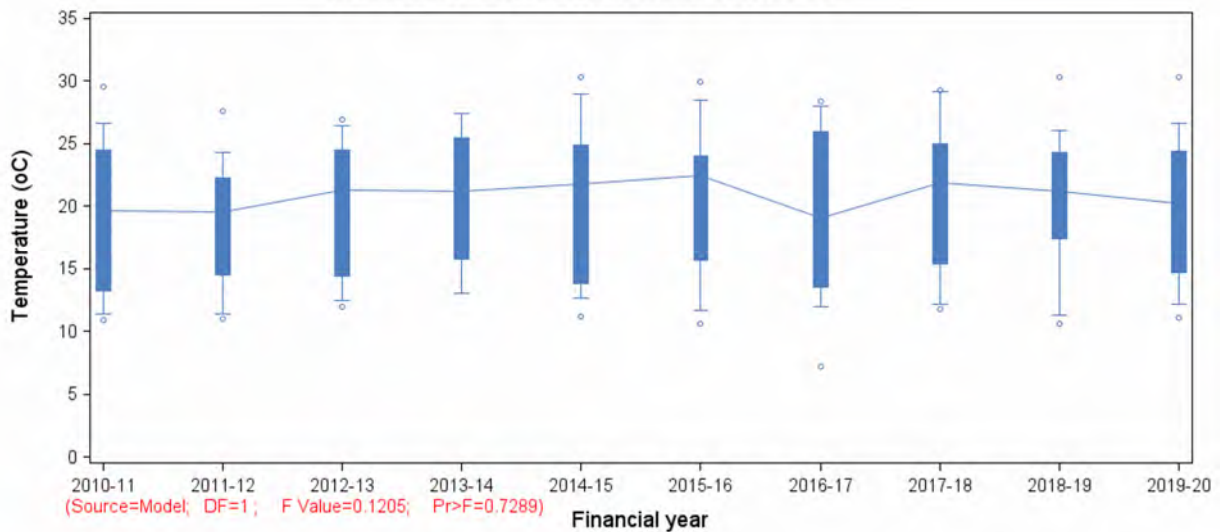
N42: Hawkesbury River at North Richmond



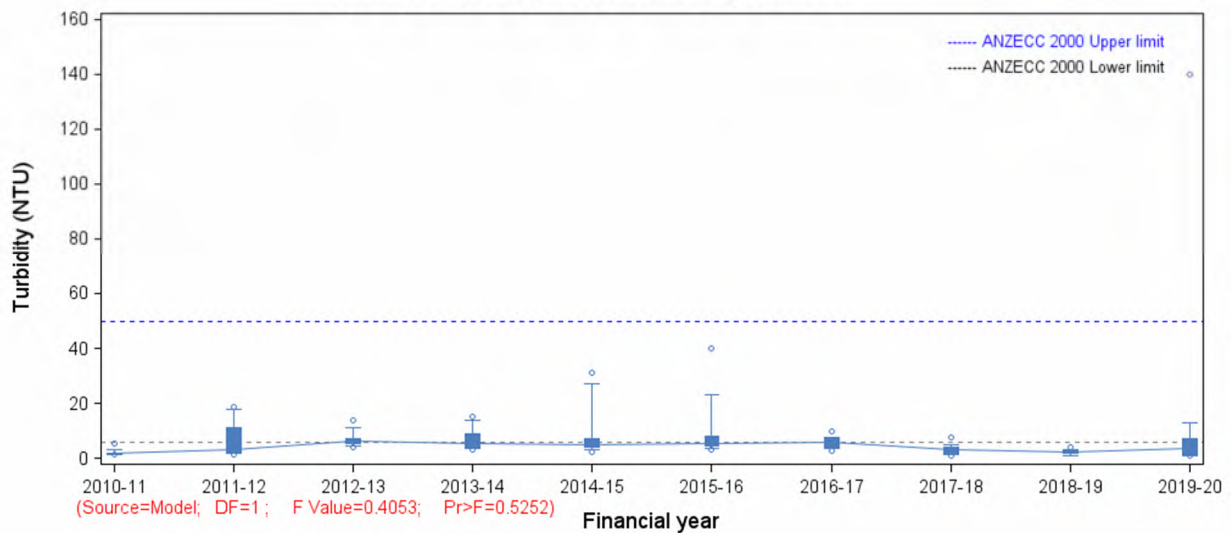
N42: Hawkesbury River at North Richmond



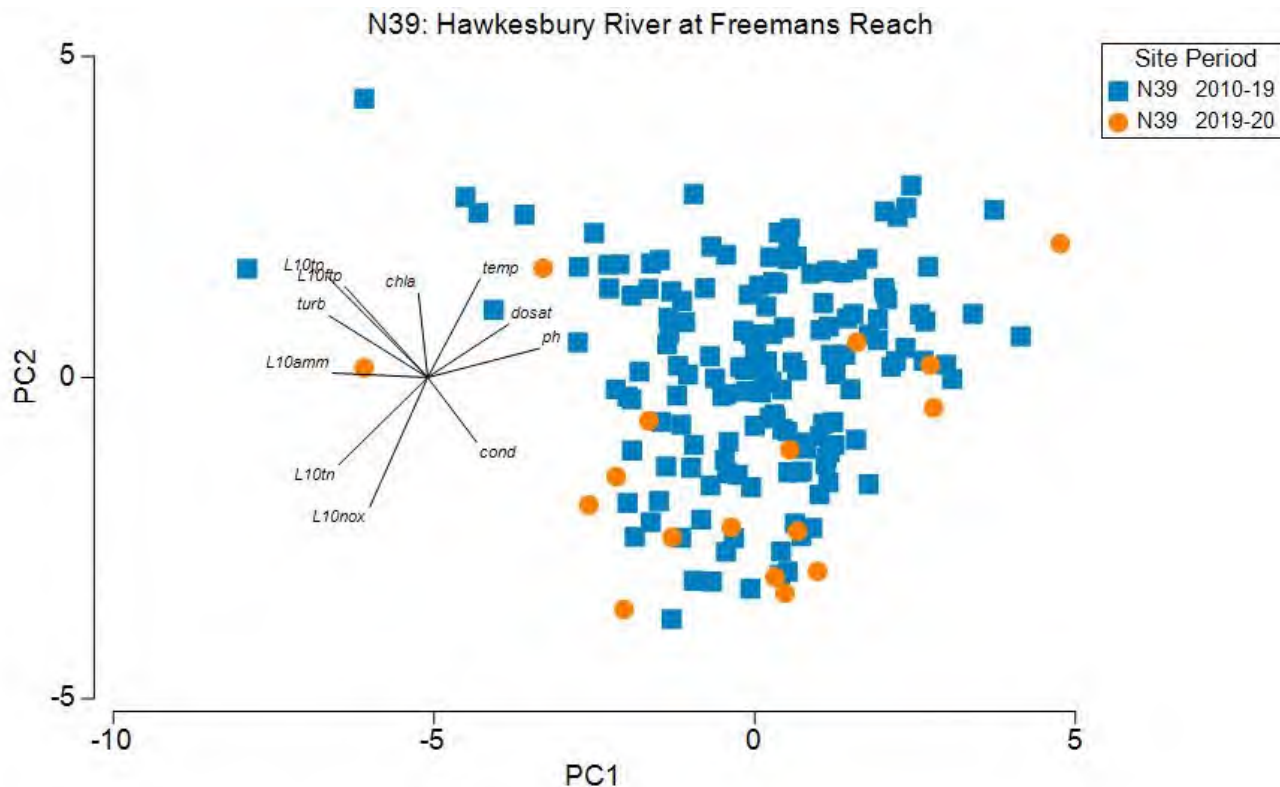
N42: Hawkesbury River at North Richmond



N42: Hawkesbury River at North Richmond

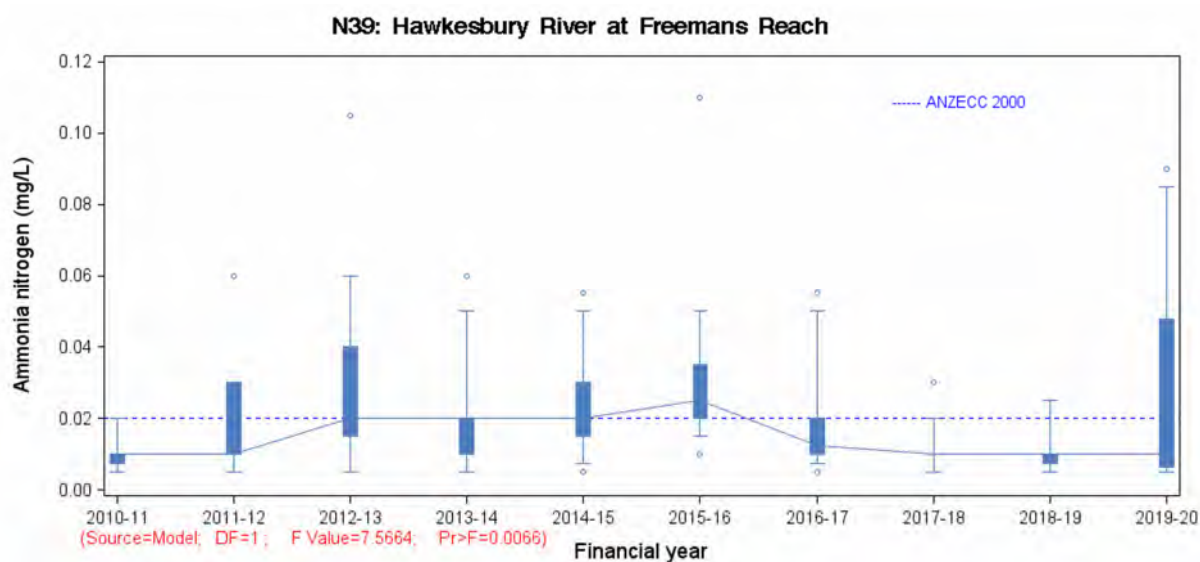


N39: Hawkesbury River at Freemans Reach

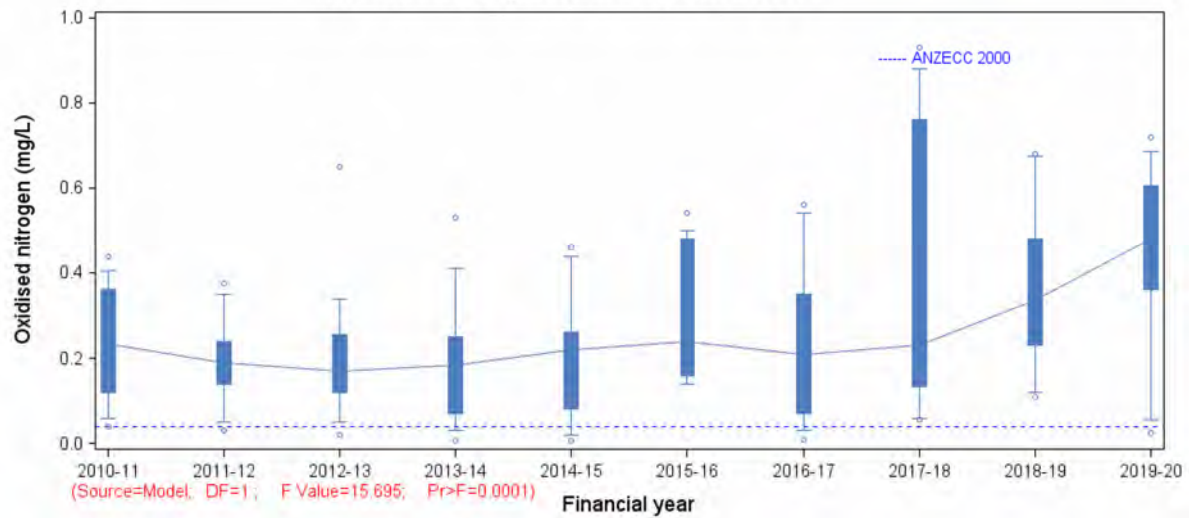


The ordination plot from Principal Components Analysis suggested water quality of the Hawkesbury River at Freemans Reach in 2019-20 was similar to that recorded in the period 2010 to 2010.

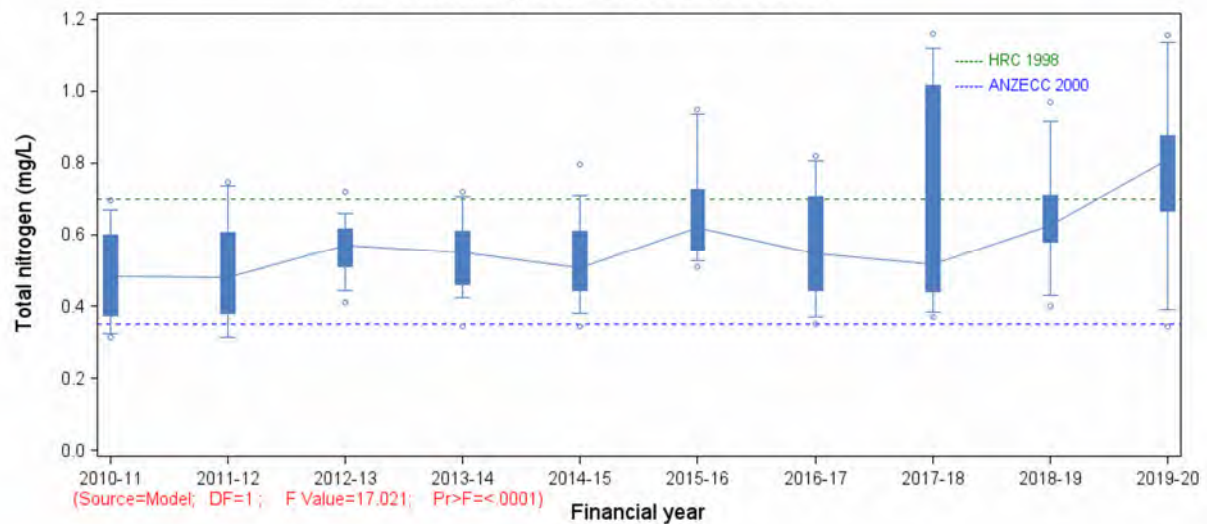
Nutrients, chlorophyll-a and algae



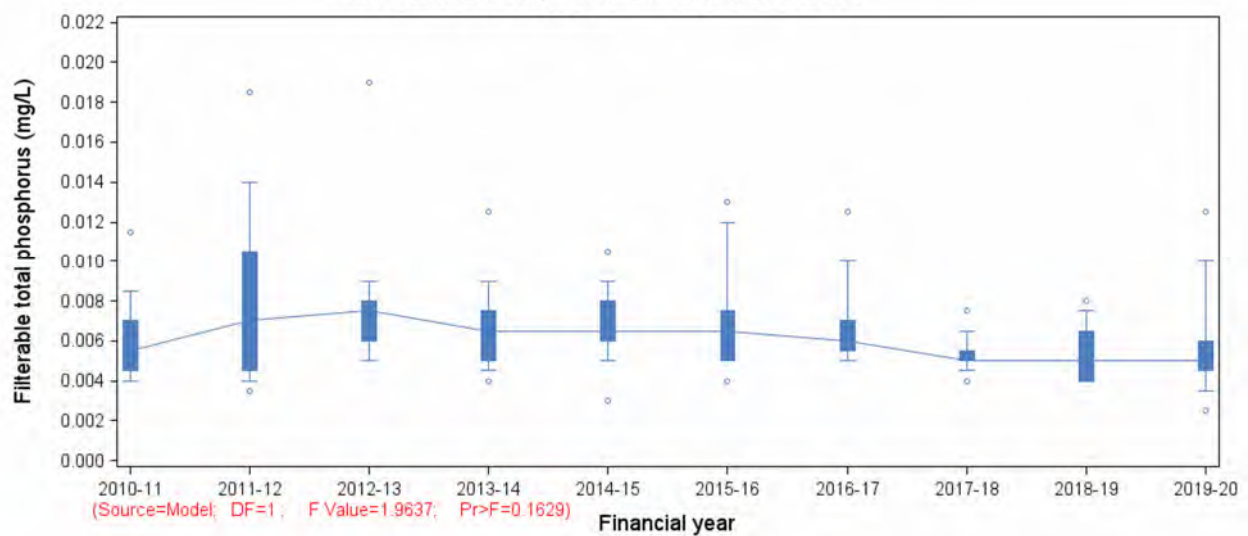
N39: Hawkesbury River at Freemans Reach



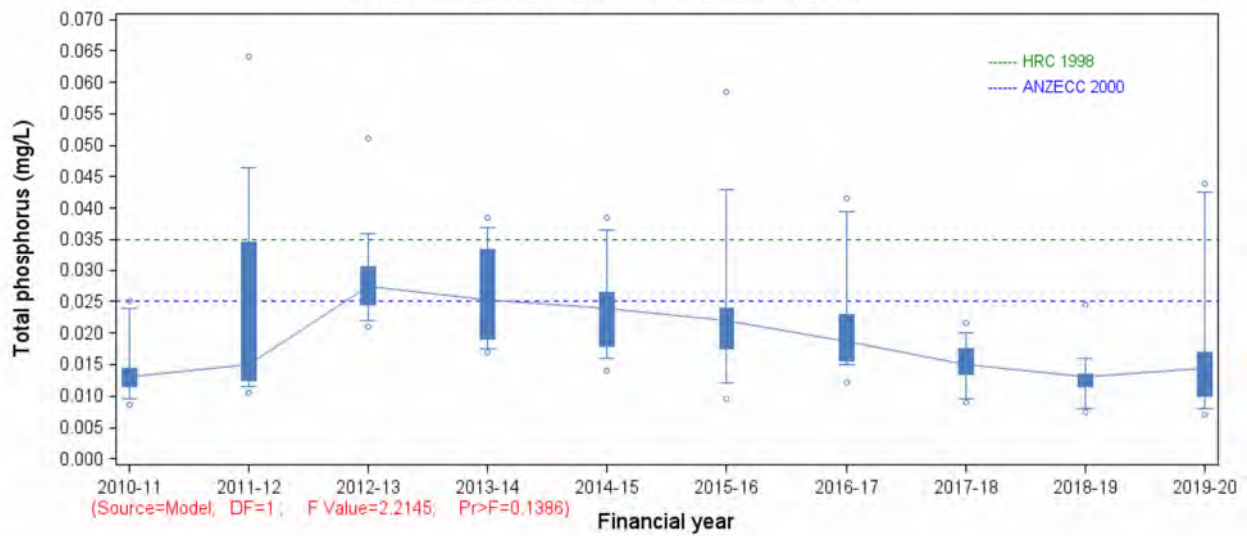
N39: Hawkesbury River at Freemans Reach



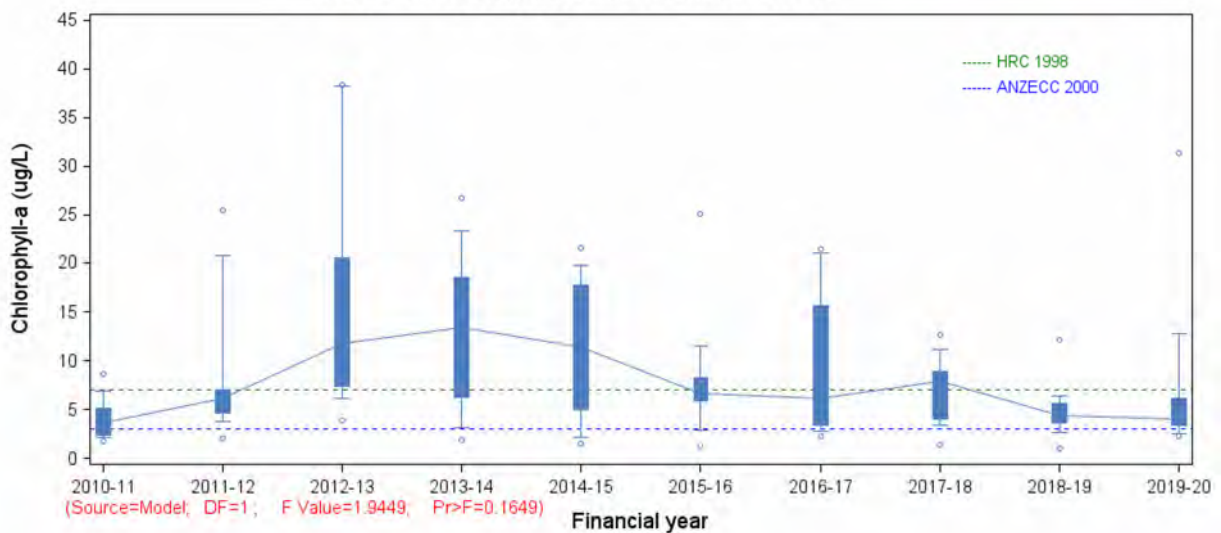
N39: Hawkesbury River at Freemans Reach



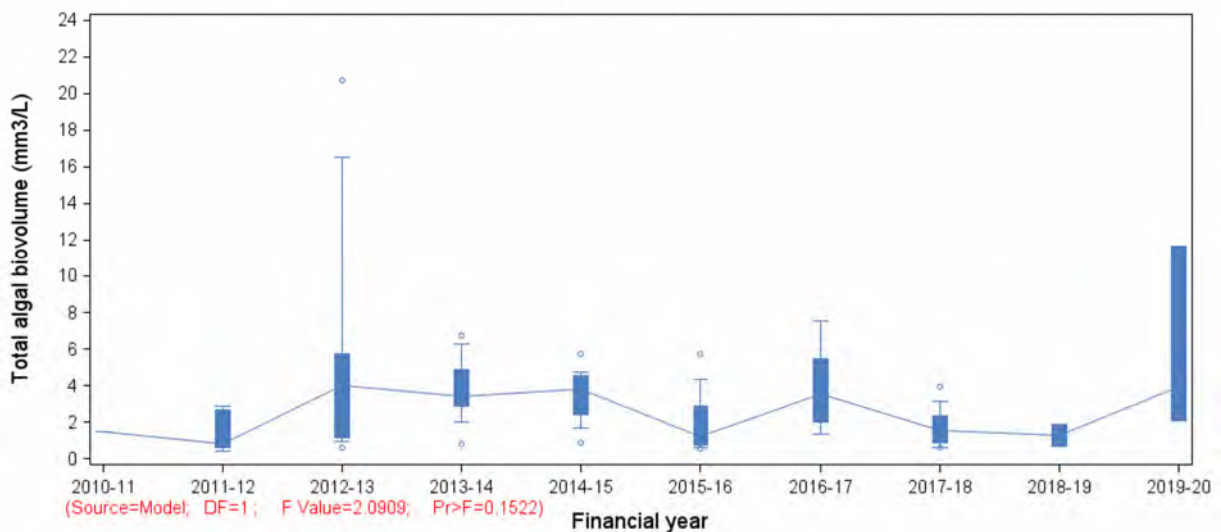
N39: Hawkesbury River at Freemans Reach



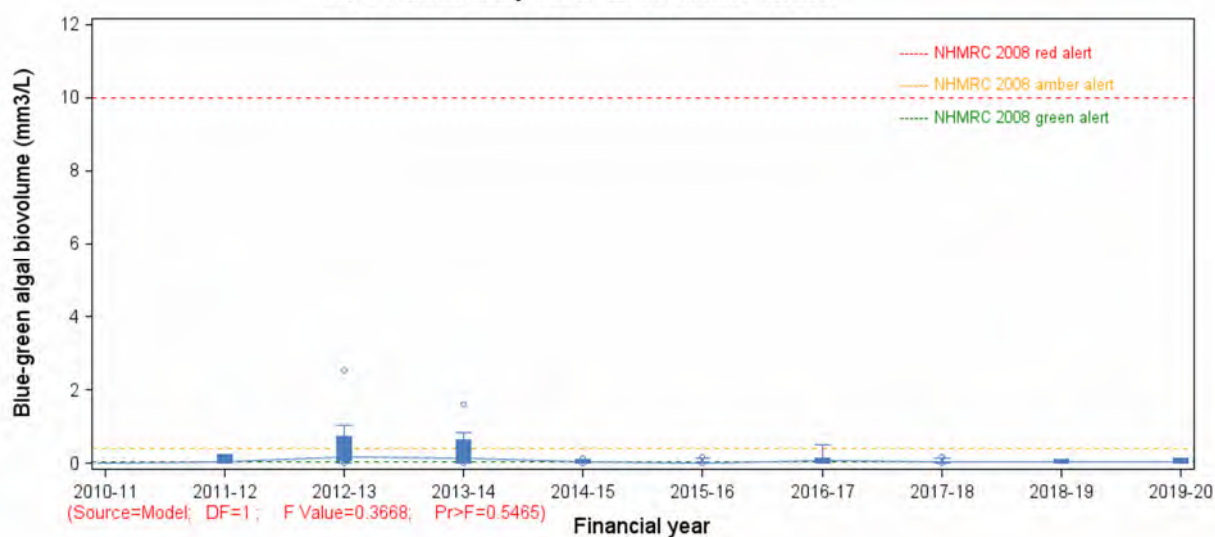
N39: Hawkesbury River at Freemans Reach



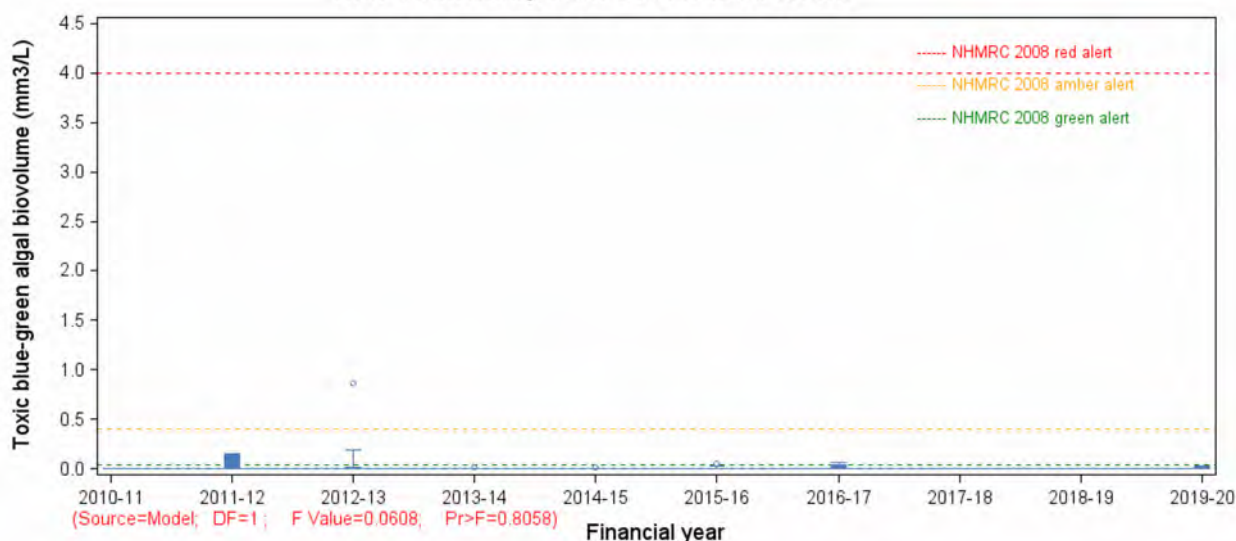
N39: Hawkesbury River at Freemans Reach



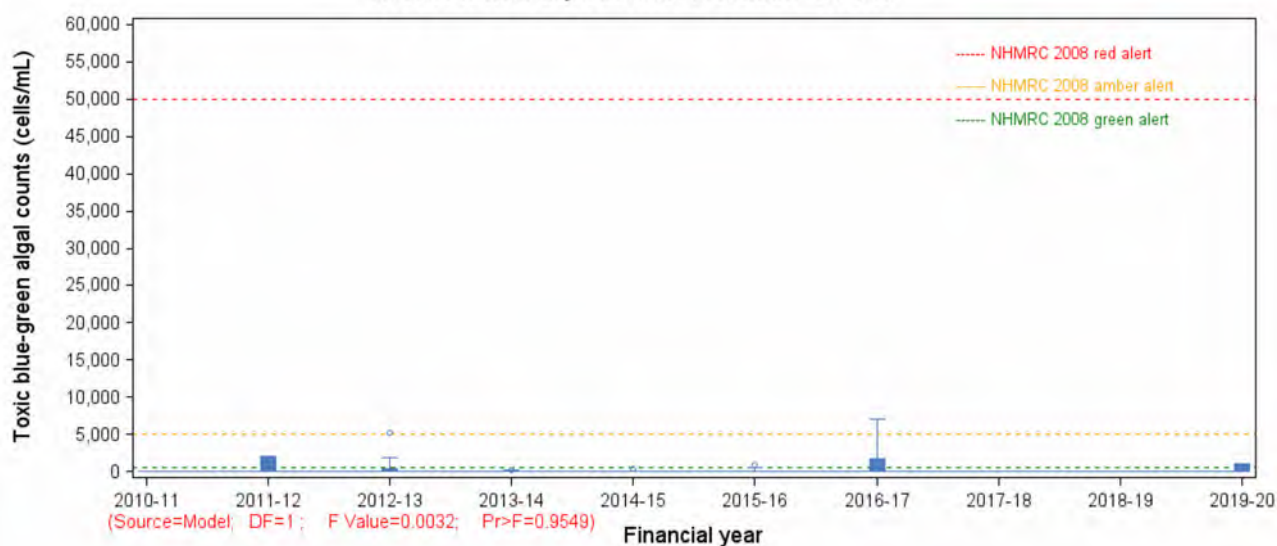
N39: Hawkesbury River at Freemans Reach

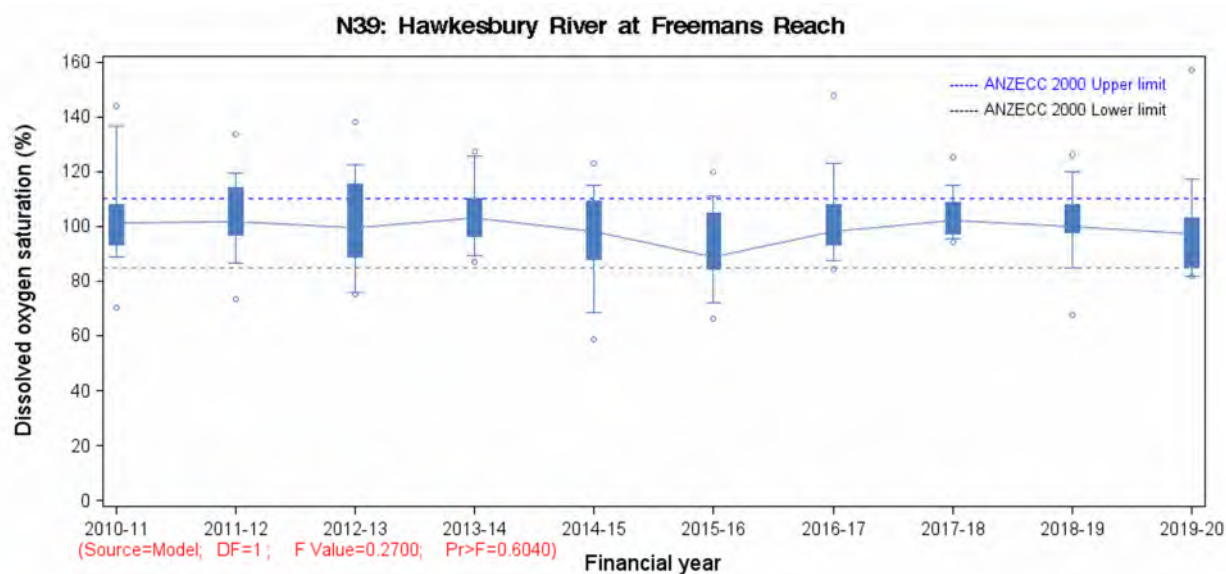
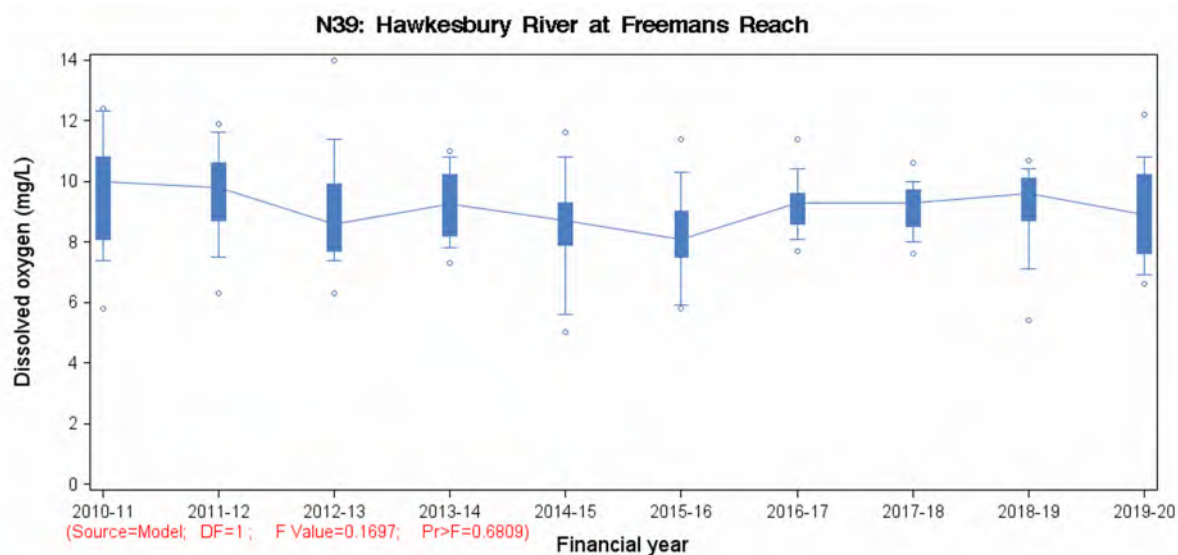
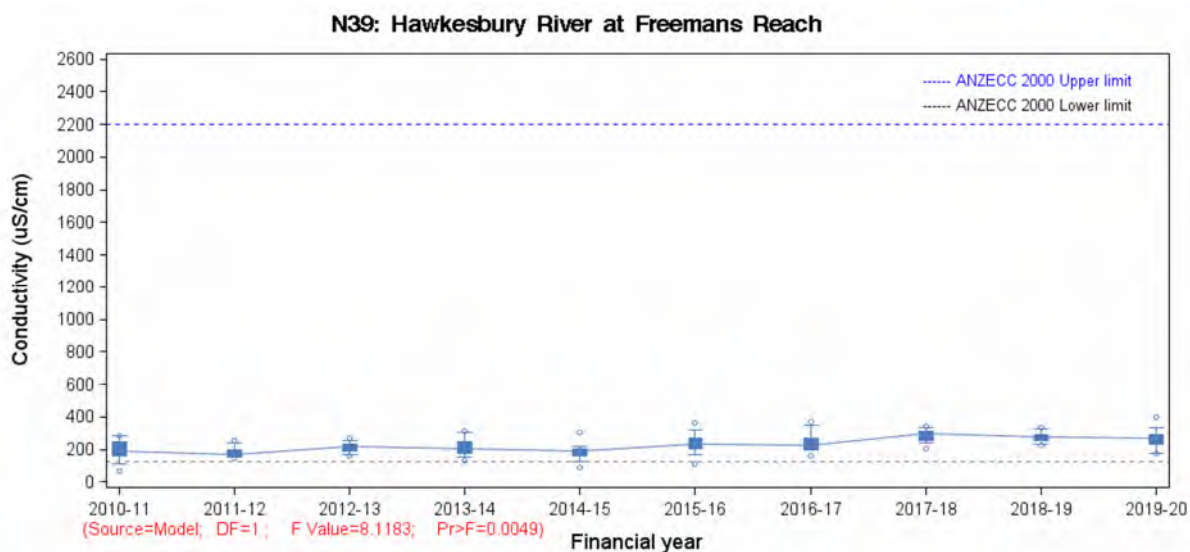


N39: Hawkesbury River at Freemans Reach

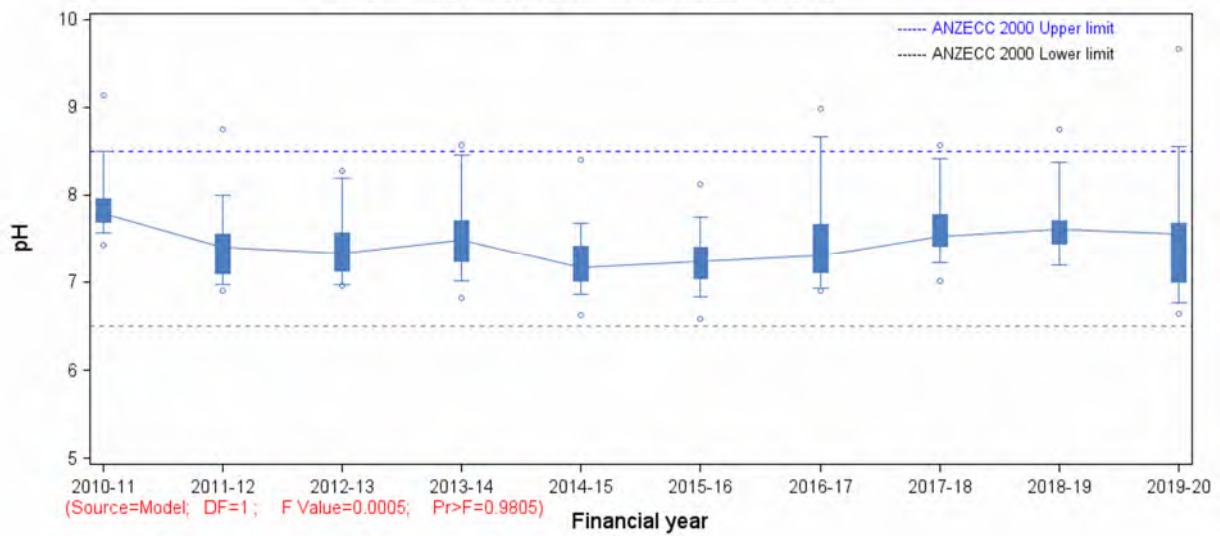


N39: Hawkesbury River at Freemans Reach

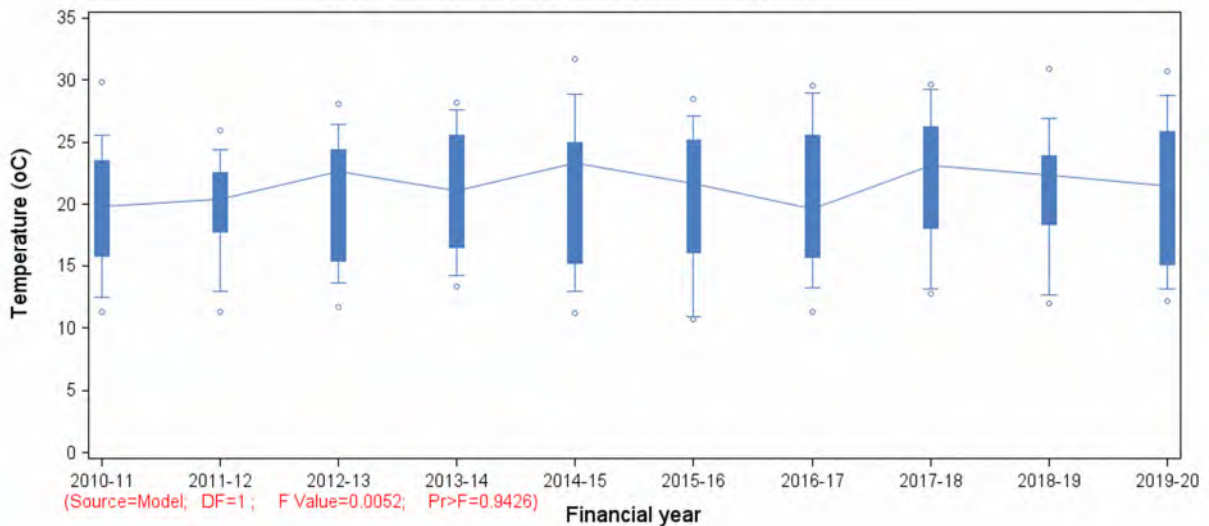




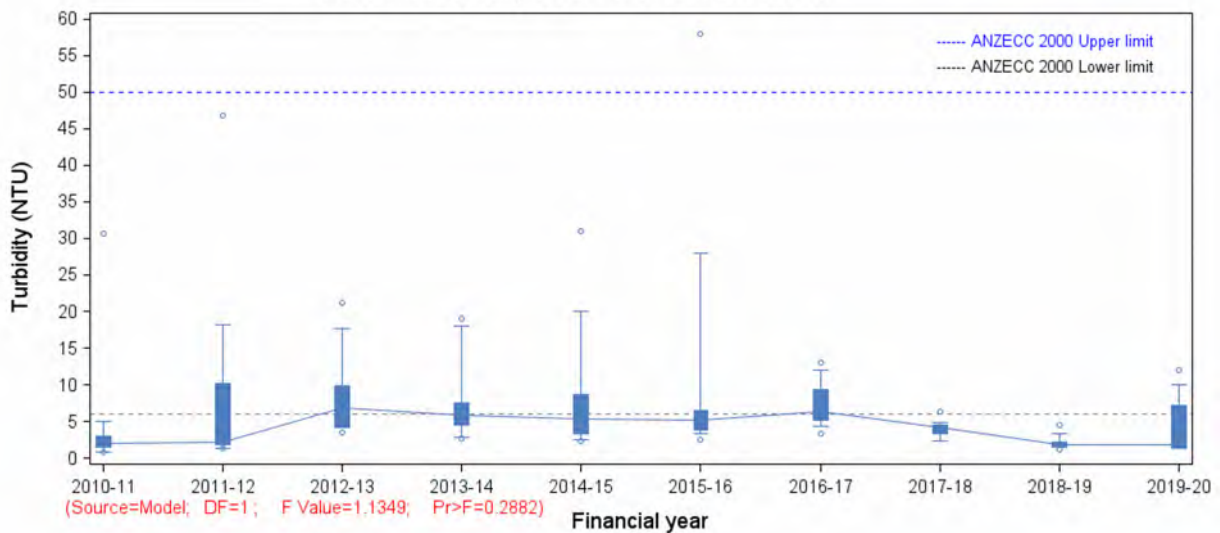
N39: Hawkesbury River at Freemans Reach



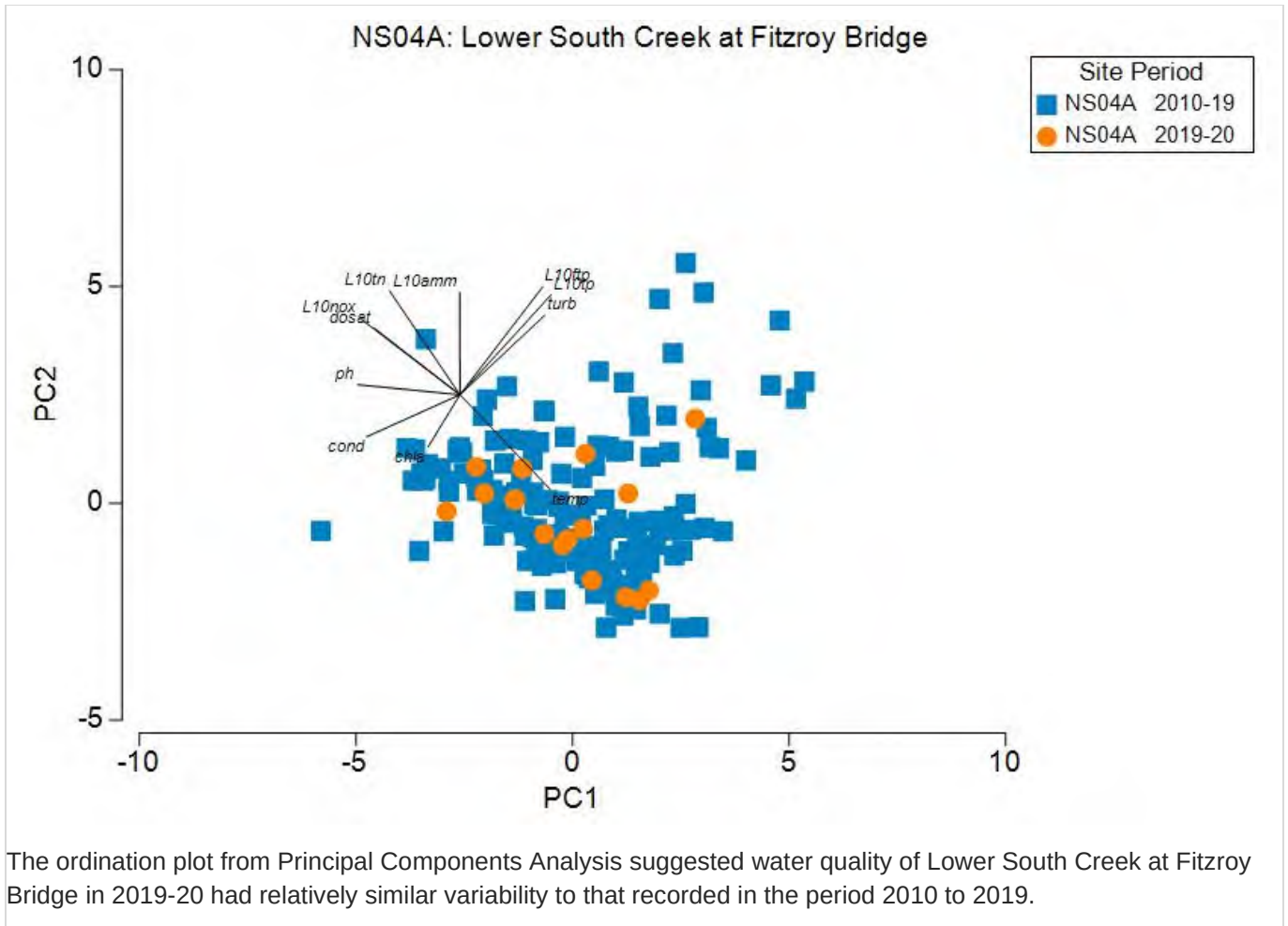
N39: Hawkesbury River at Freemans Reach



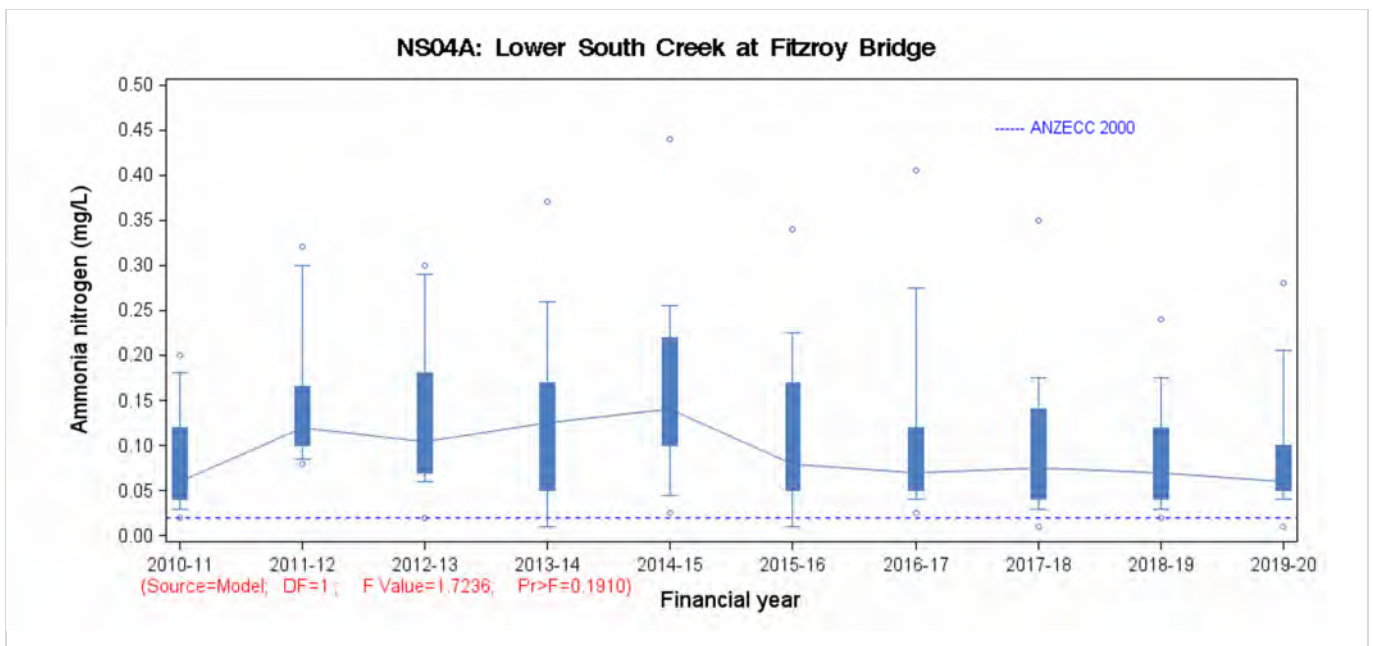
N39: Hawkesbury River at Freemans Reach



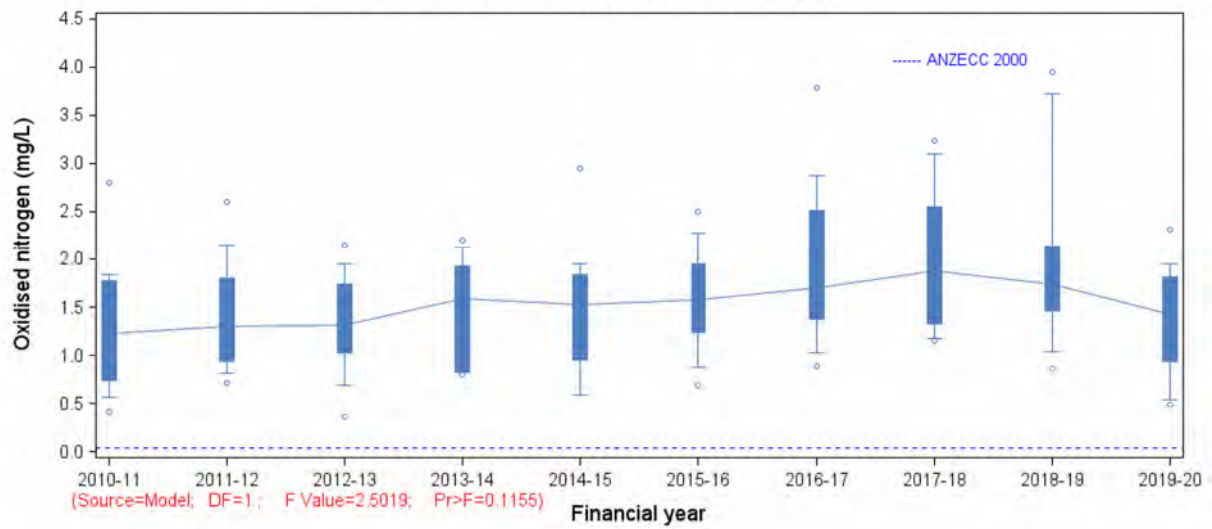
NS04A: Lower South Creek at Fitzroy Bridge



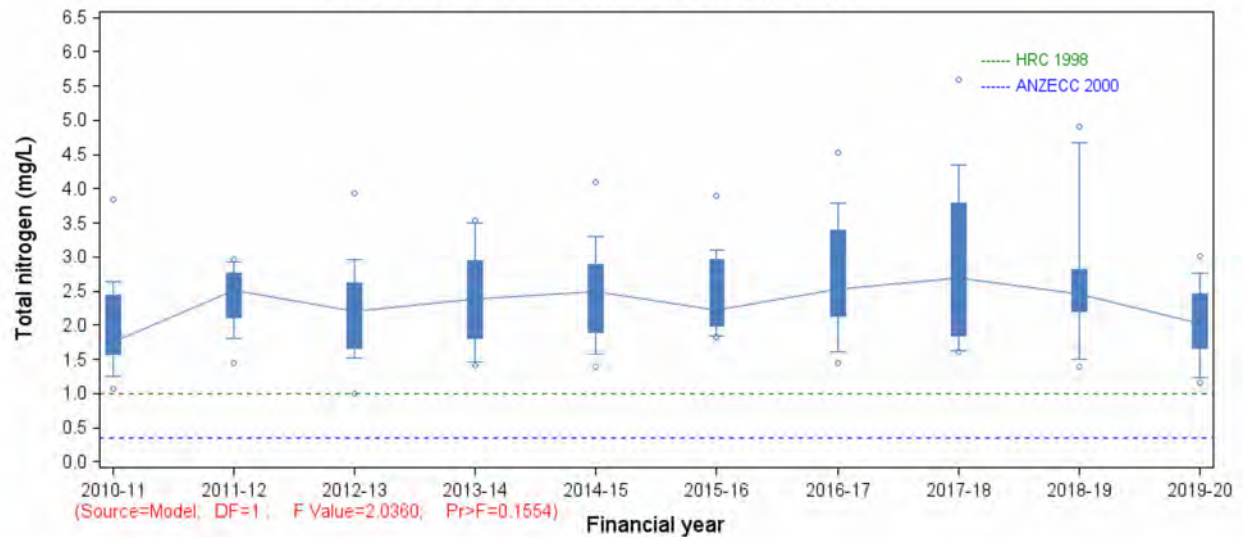
Nutrients, chlorophyll-a and algae



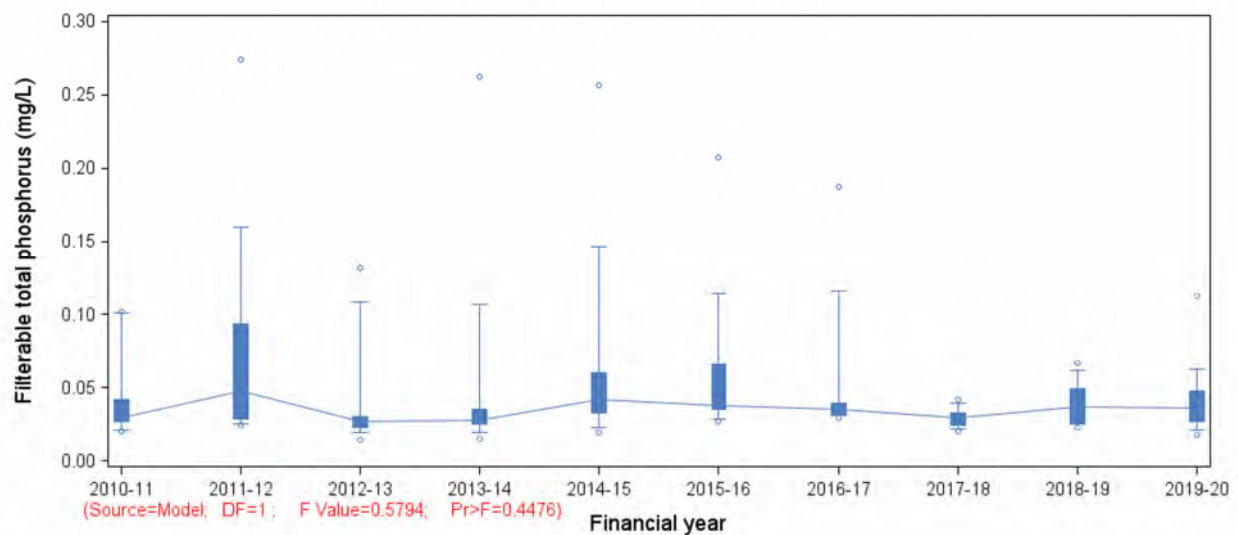
NS04A: Lower South Creek at Fitzroy Bridge



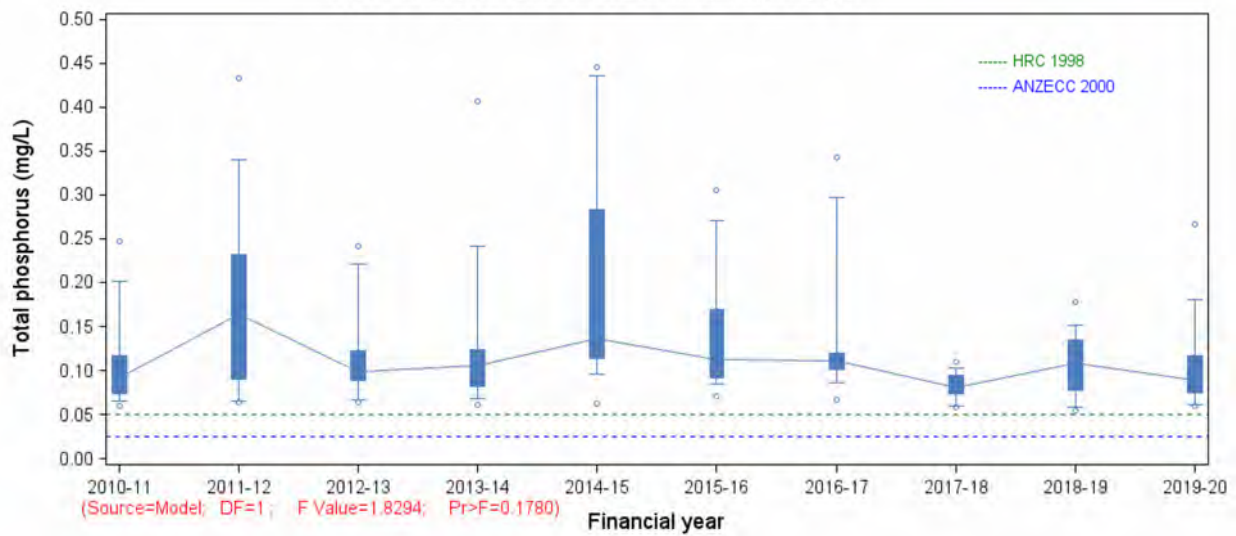
NS04A: Lower South Creek at Fitzroy Bridge



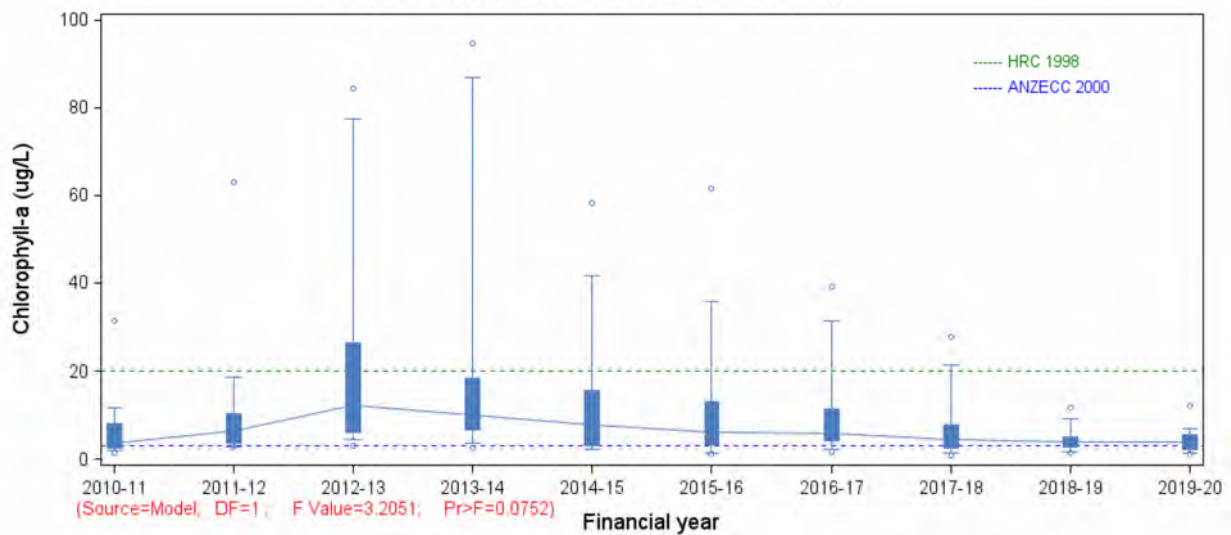
NS04A: Lower South Creek at Fitzroy Bridge



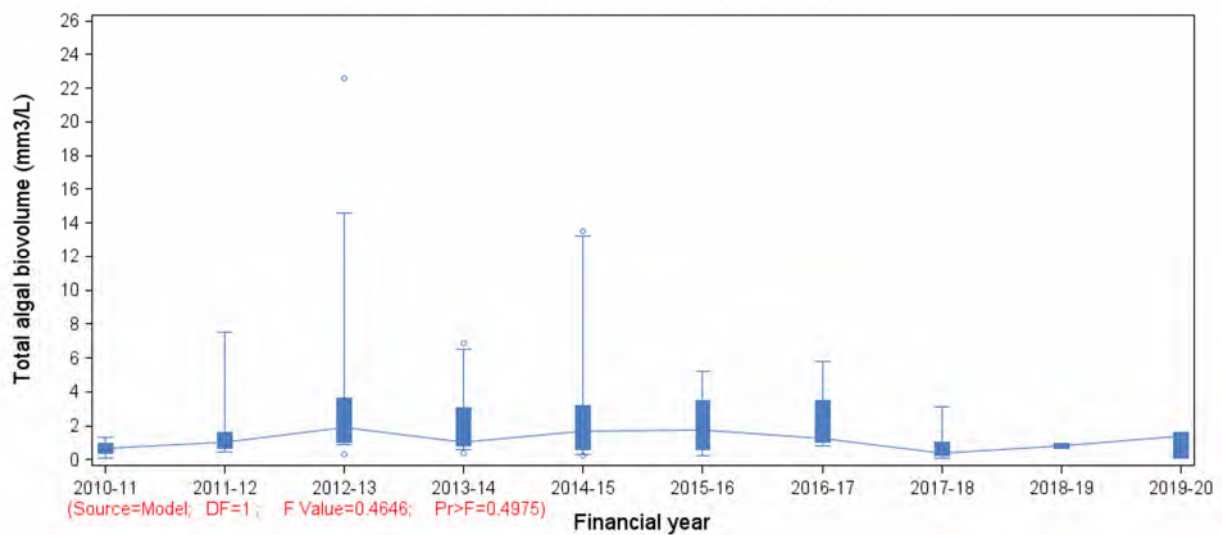
NS04A: Lower South Creek at Fitzroy Bridge



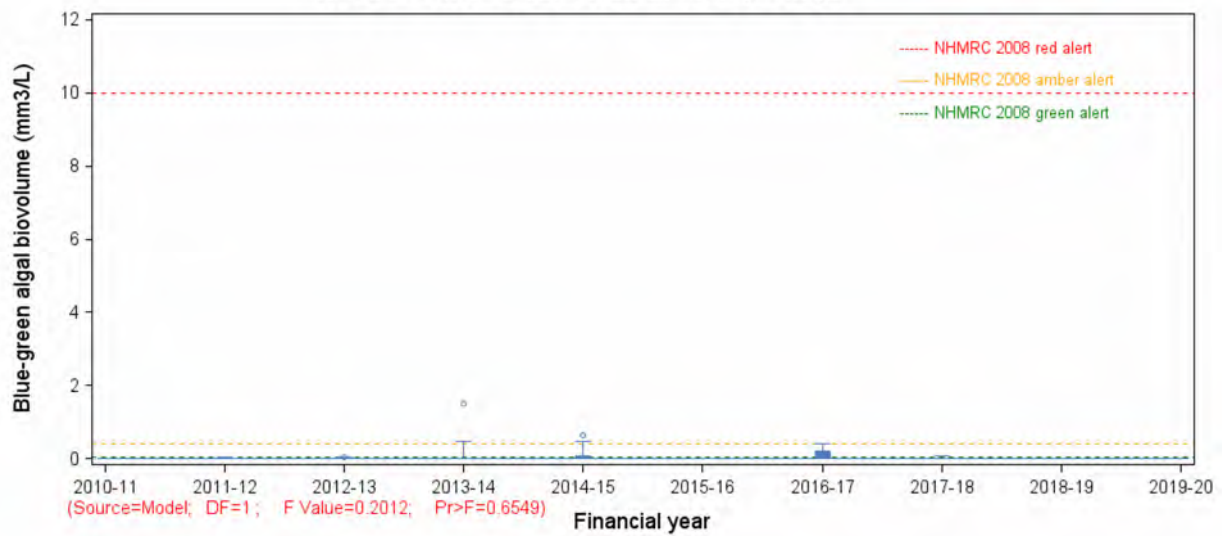
NS04A: Lower South Creek at Fitzroy Bridge



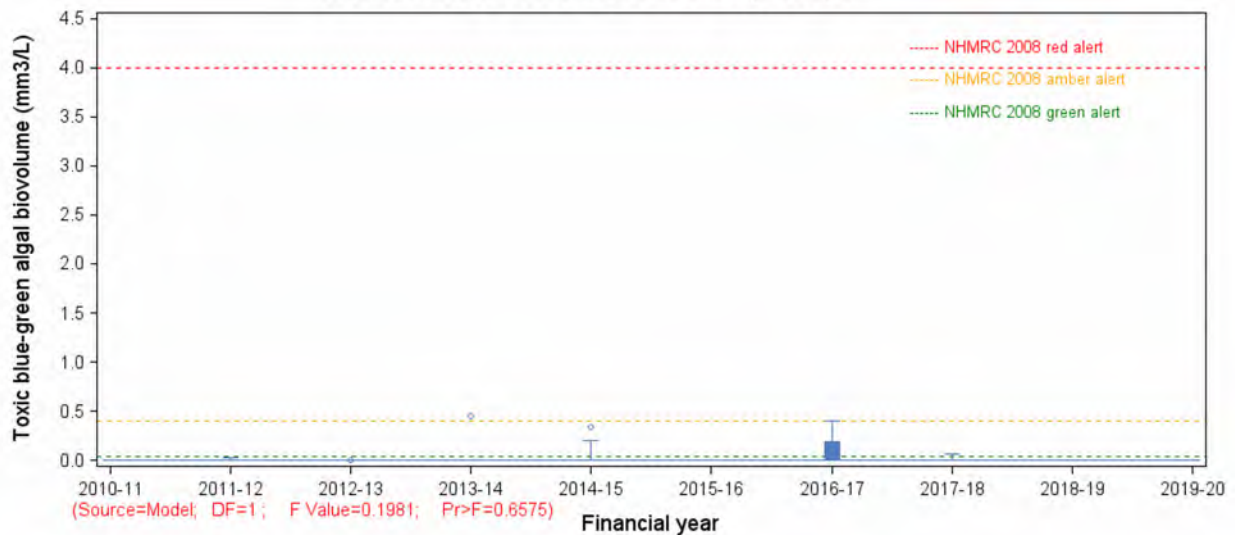
NS04A: Lower South Creek at Fitzroy Bridge



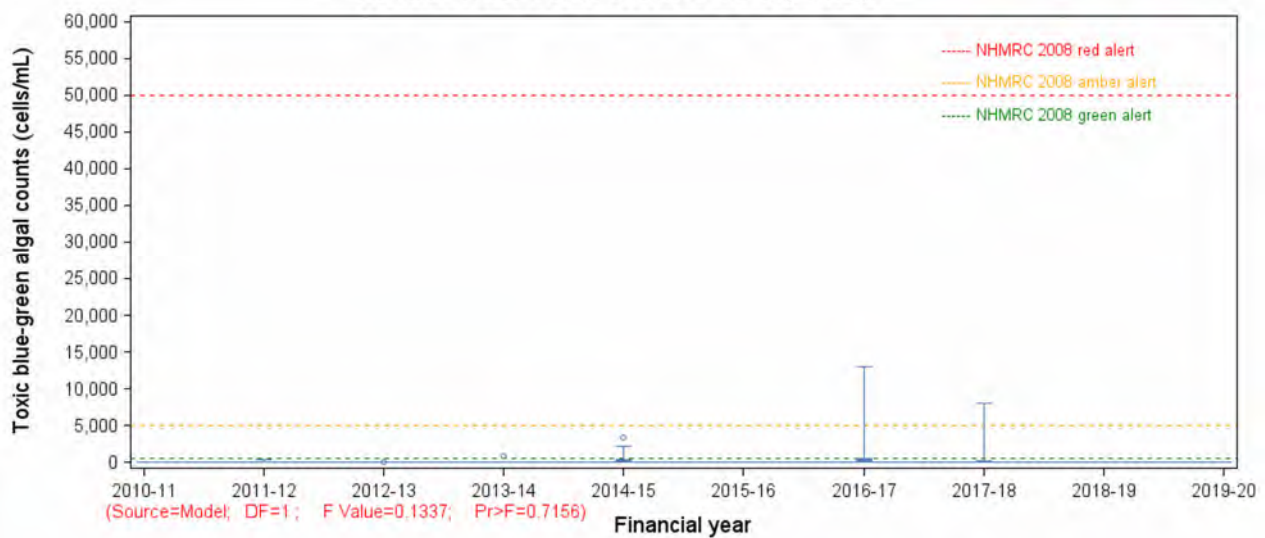
NS04A: Lower South Creek at Fitzroy Bridge



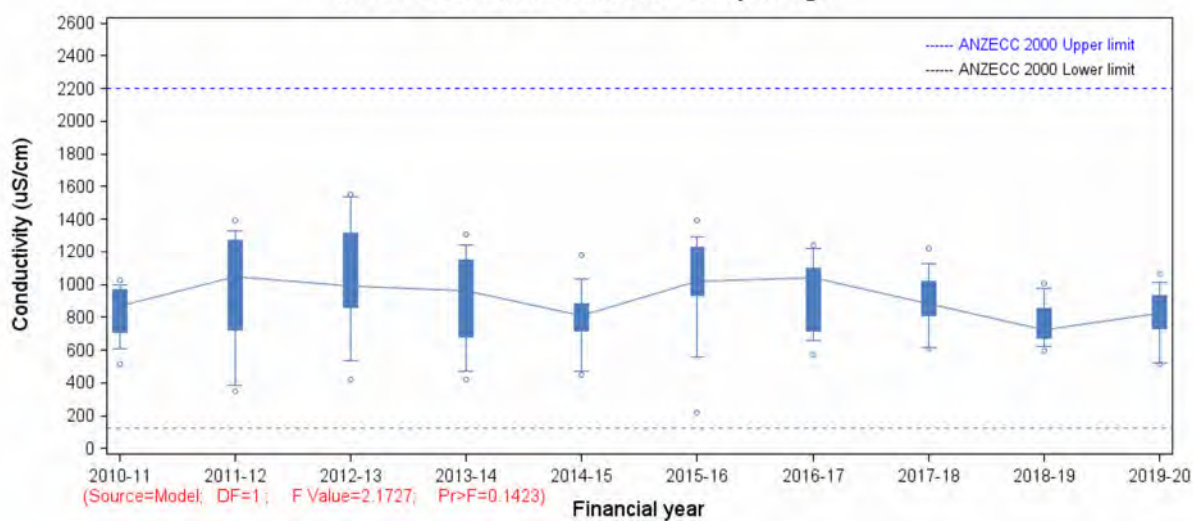
NS04A: Lower South Creek at Fitzroy Bridge



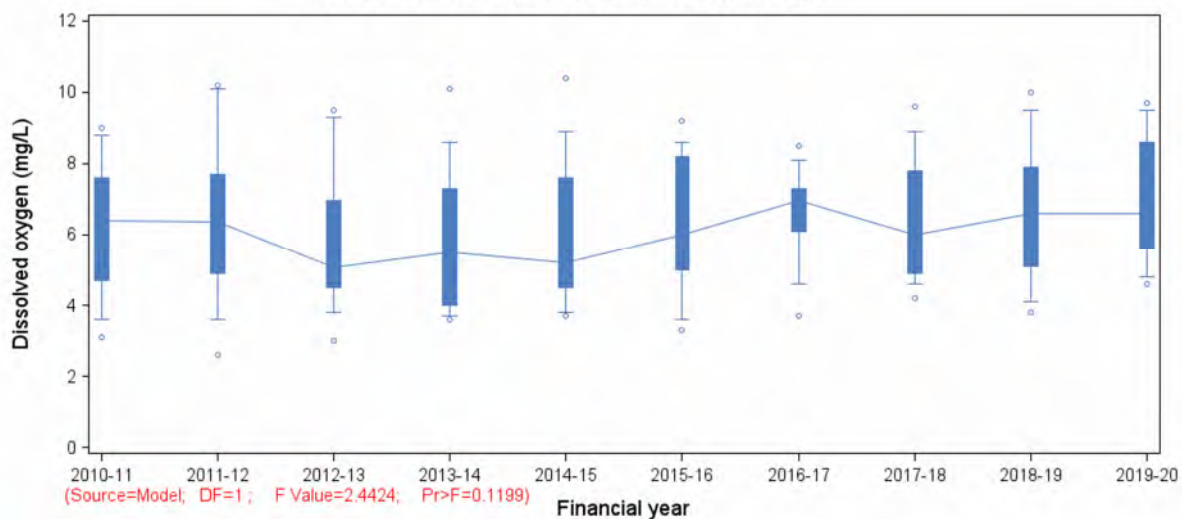
NS04A: Lower South Creek at Fitzroy Bridge



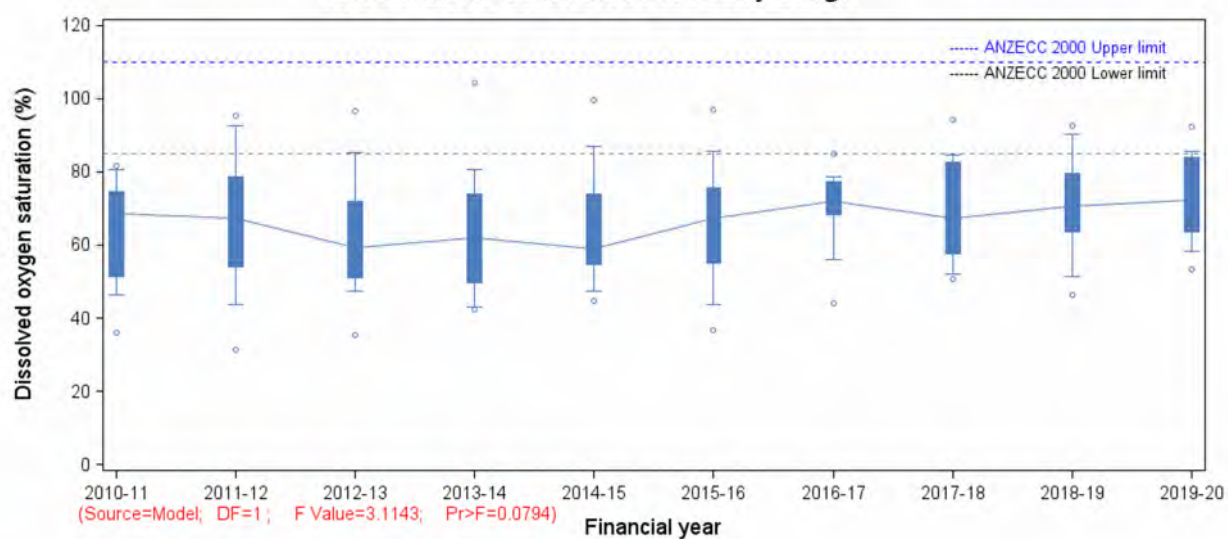
NS04A: Lower South Creek at Fitzroy Bridge



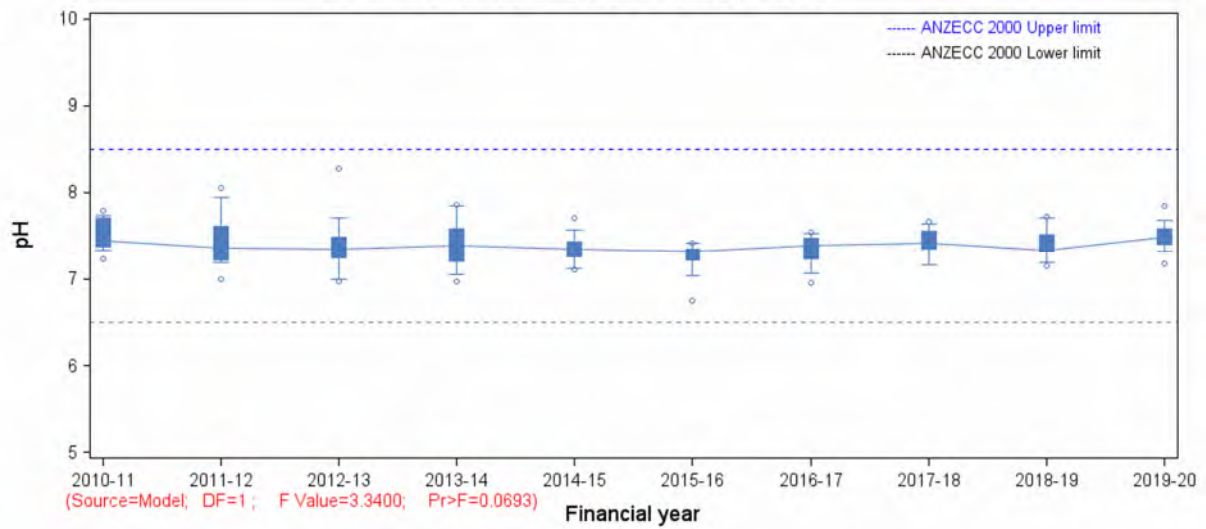
NS04A: Lower South Creek at Fitzroy Bridge



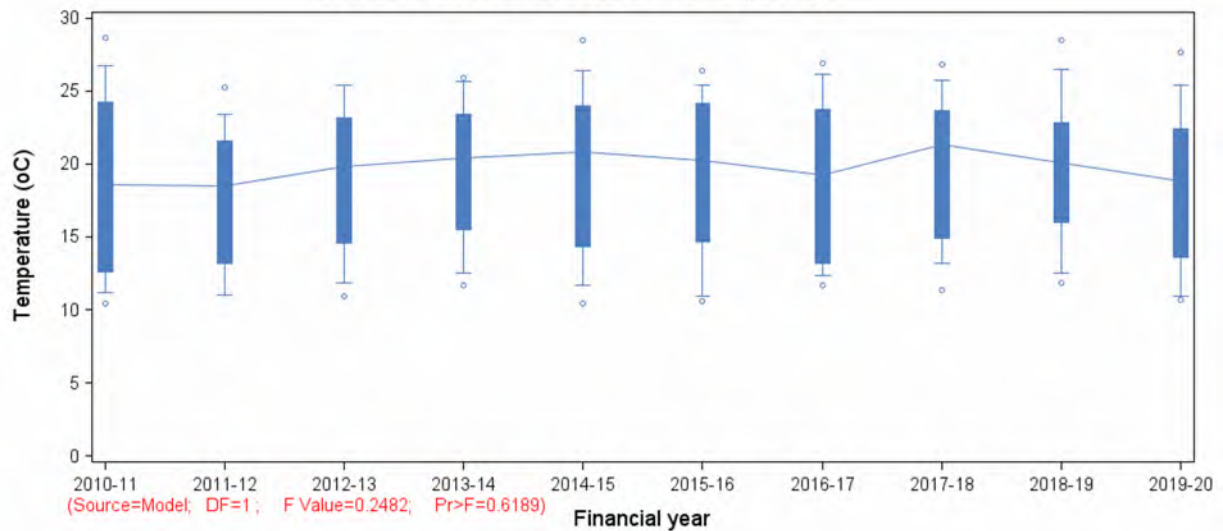
NS04A: Lower South Creek at Fitzroy Bridge



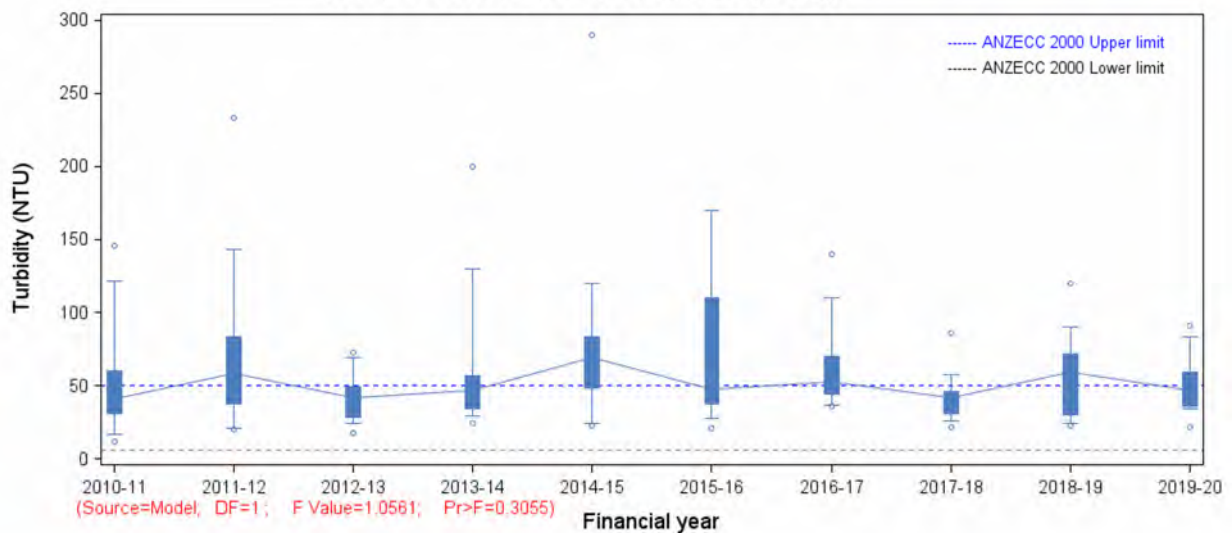
NS04A: Lower South Creek at Fitzroy Bridge



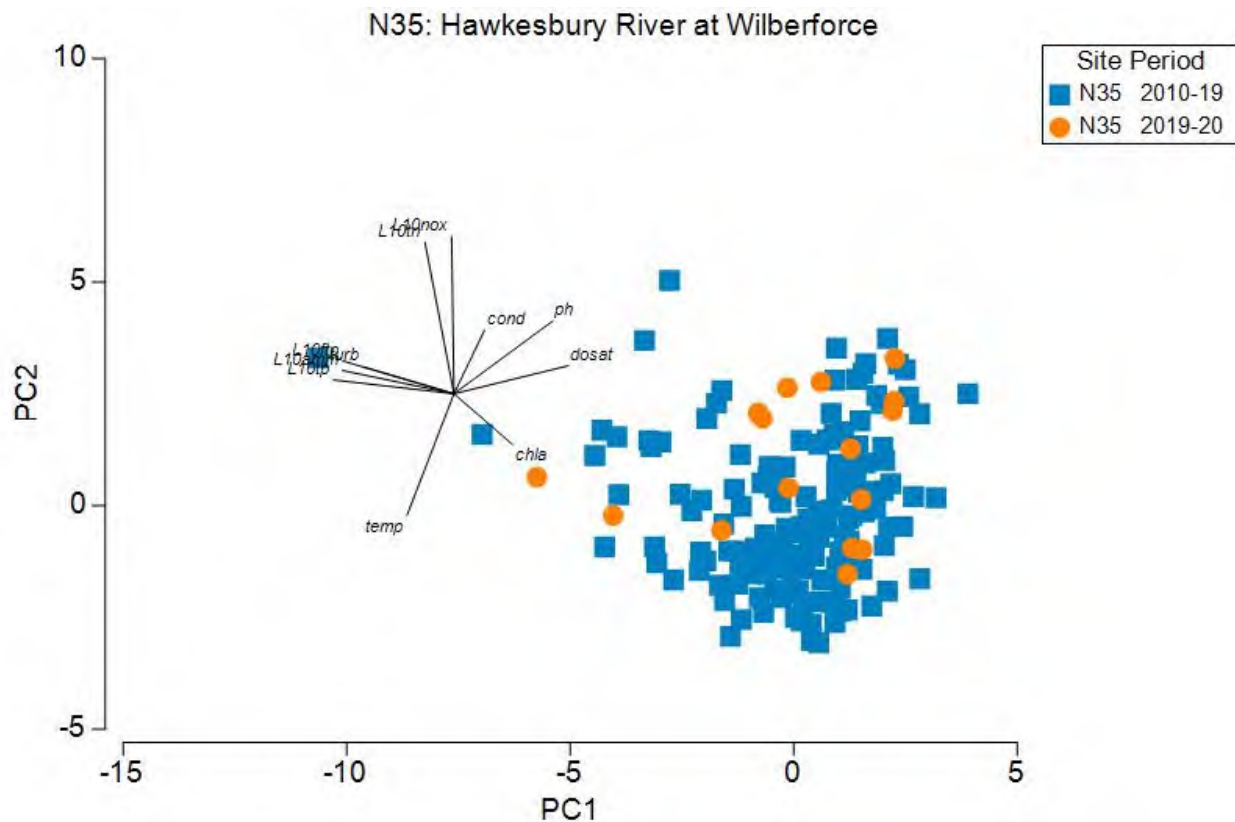
NS04A: Lower South Creek at Fitzroy Bridge



NS04A: Lower South Creek at Fitzroy Bridge

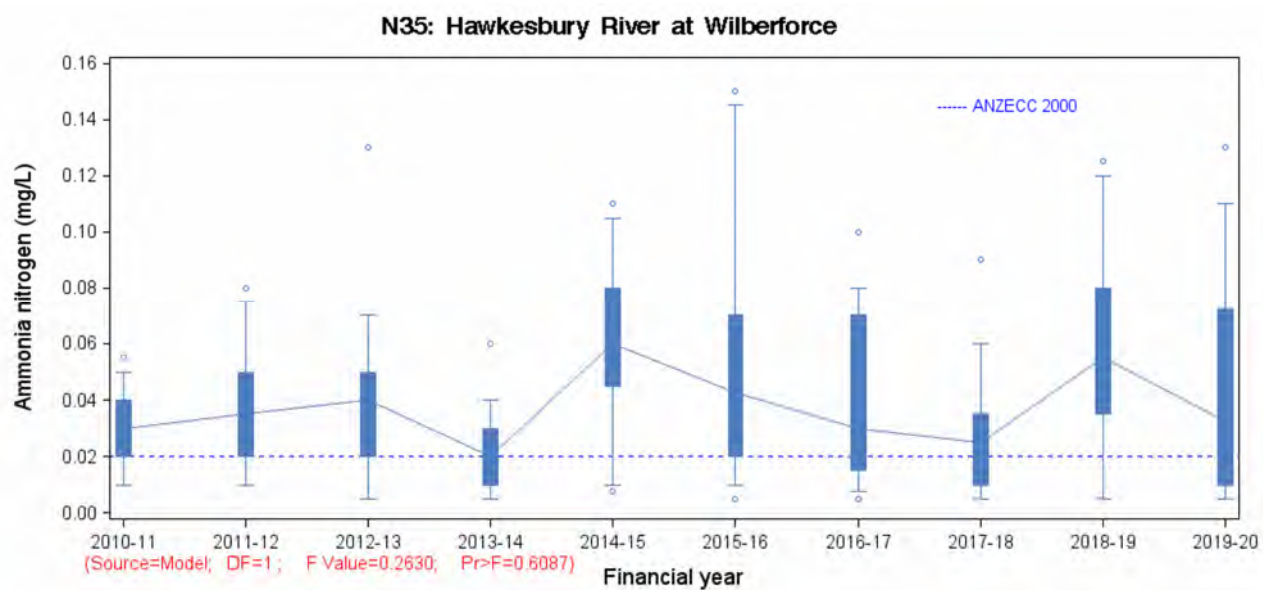


N35: Hawkesbury River at Wilberforce

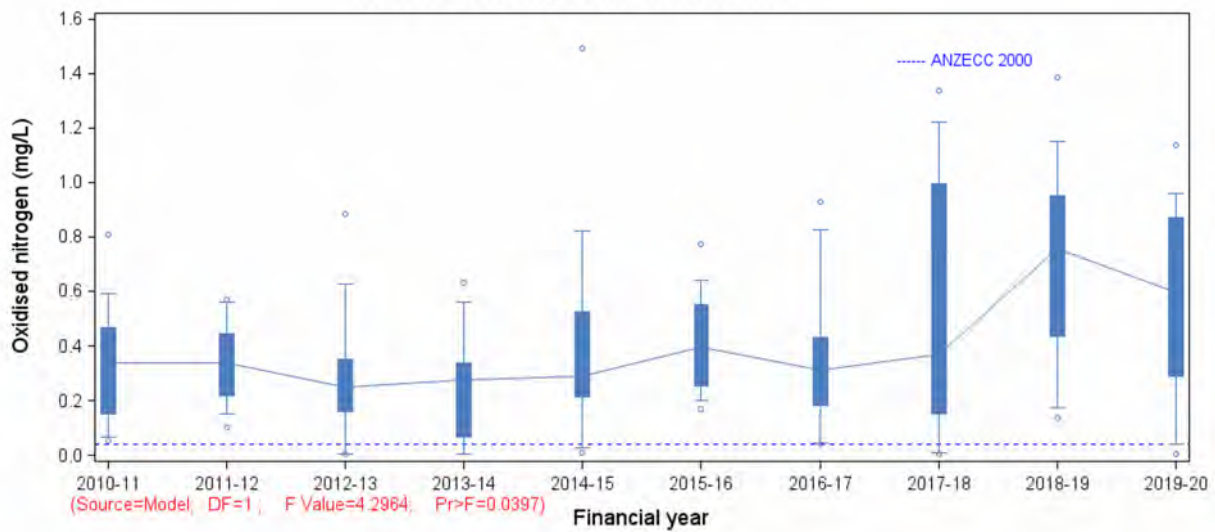


The ordination plot from Principal Components Analysis suggested water quality of the Hawkesbury River at Wilberforce in 2019-20 was similar to that recorded in the period 2010 to 2019.

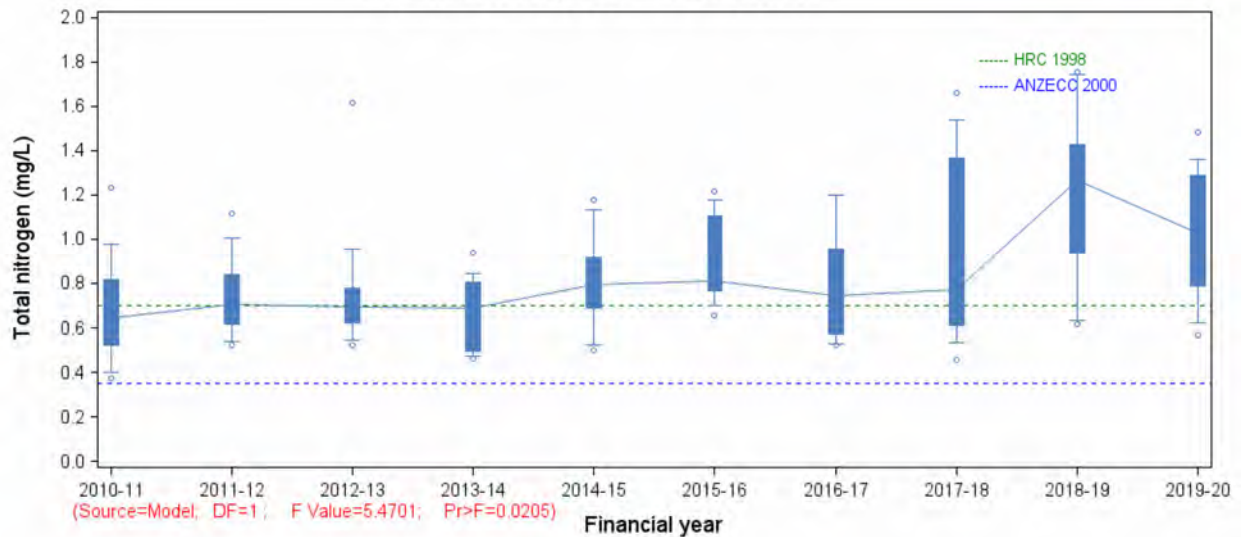
Nutrients, chlorophyll-a and algae



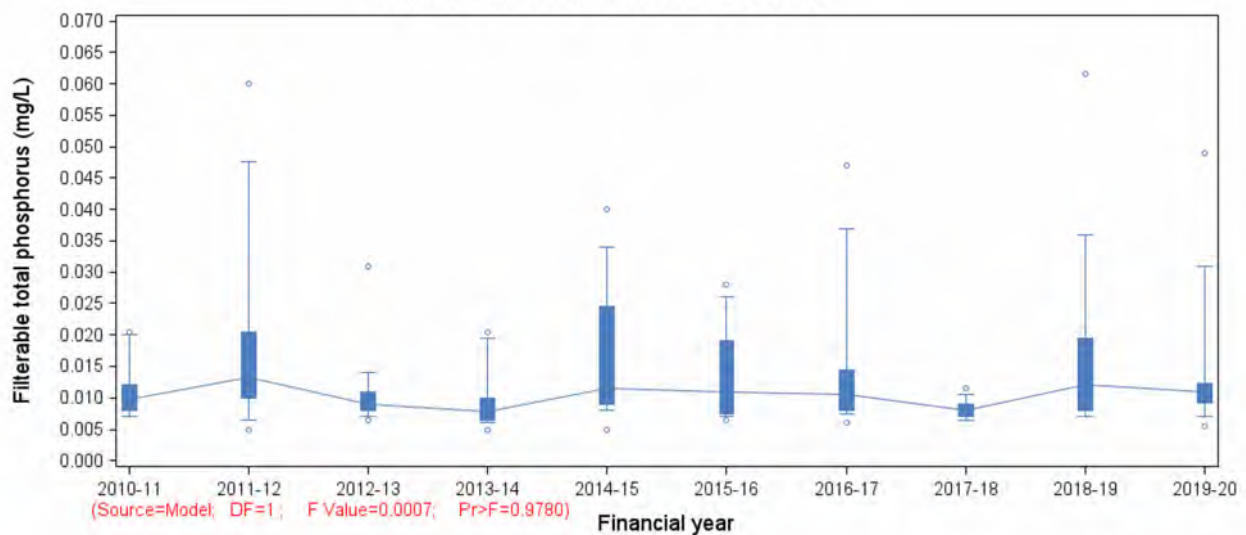
N35: Hawkesbury River at Wilberforce



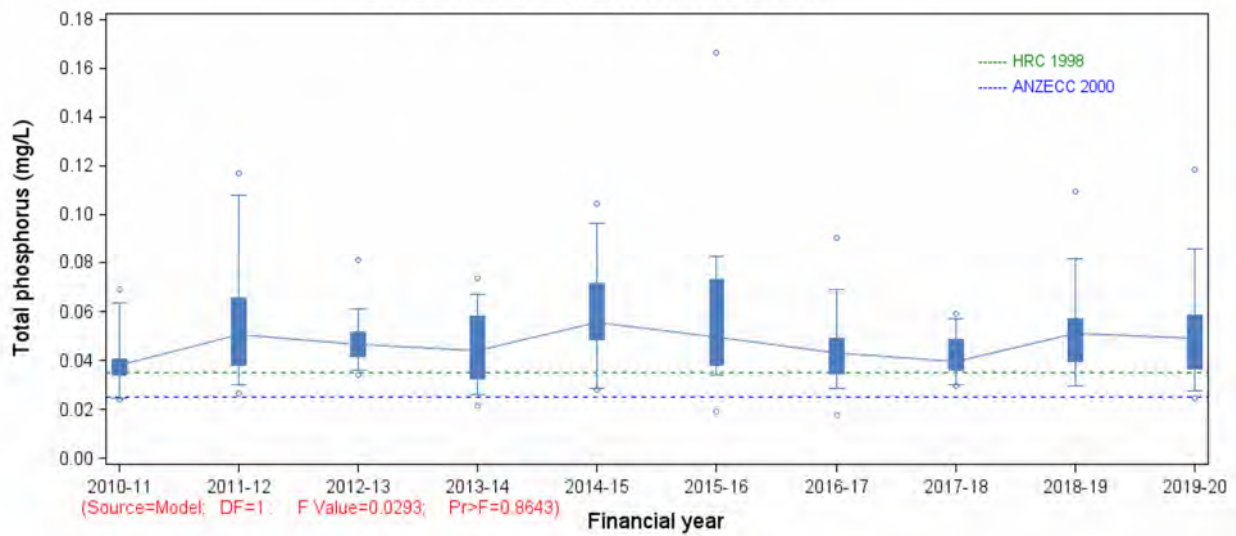
N35: Hawkesbury River at Wilberforce



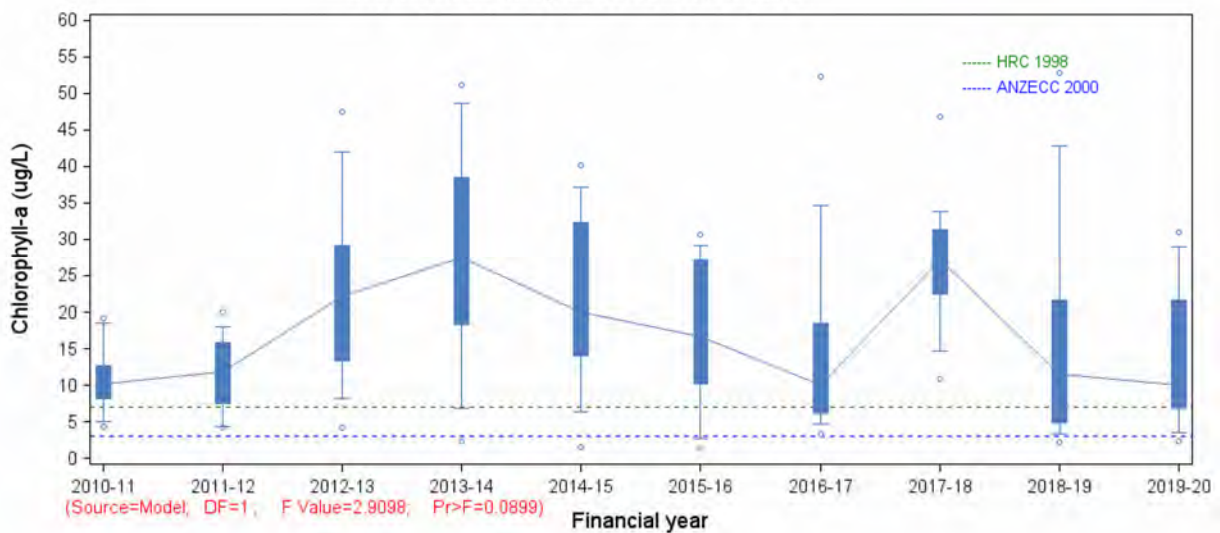
N35: Hawkesbury River at Wilberforce



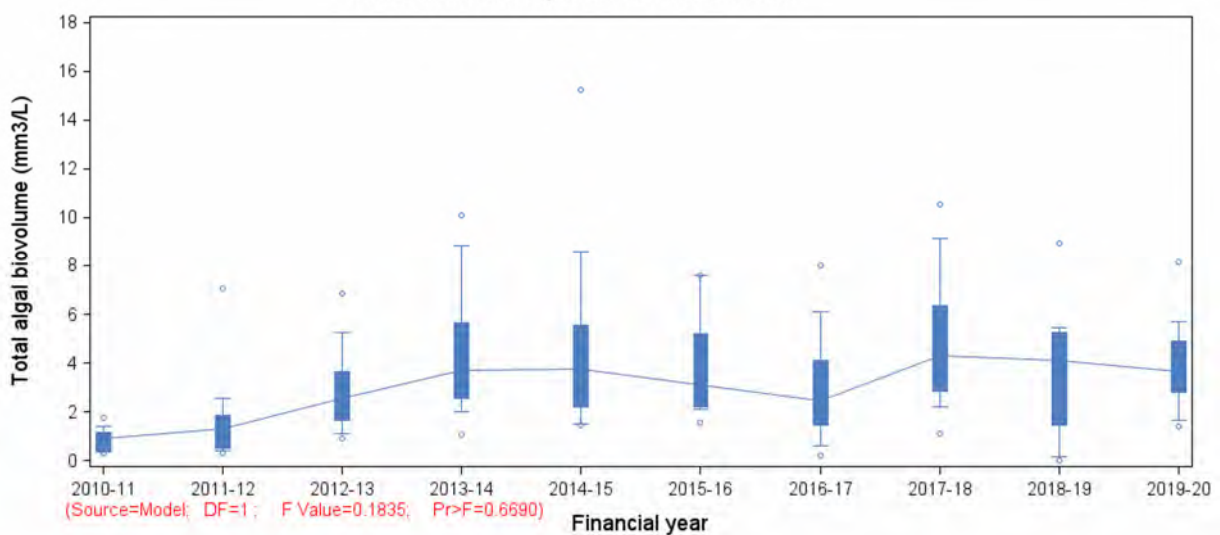
N35: Hawkesbury River at Wilberforce



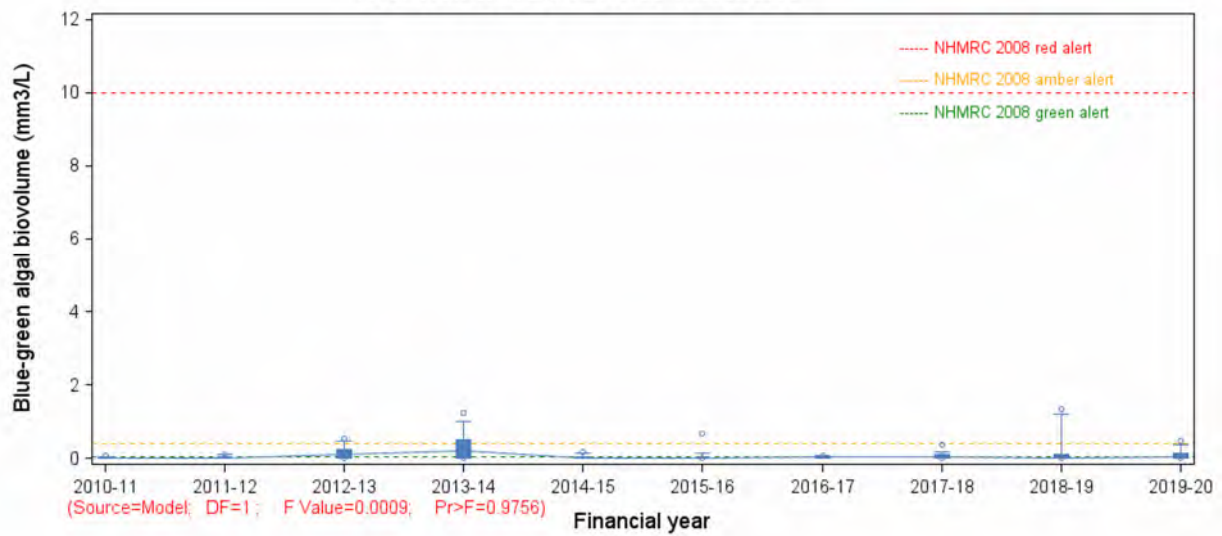
N35: Hawkesbury River at Wilberforce



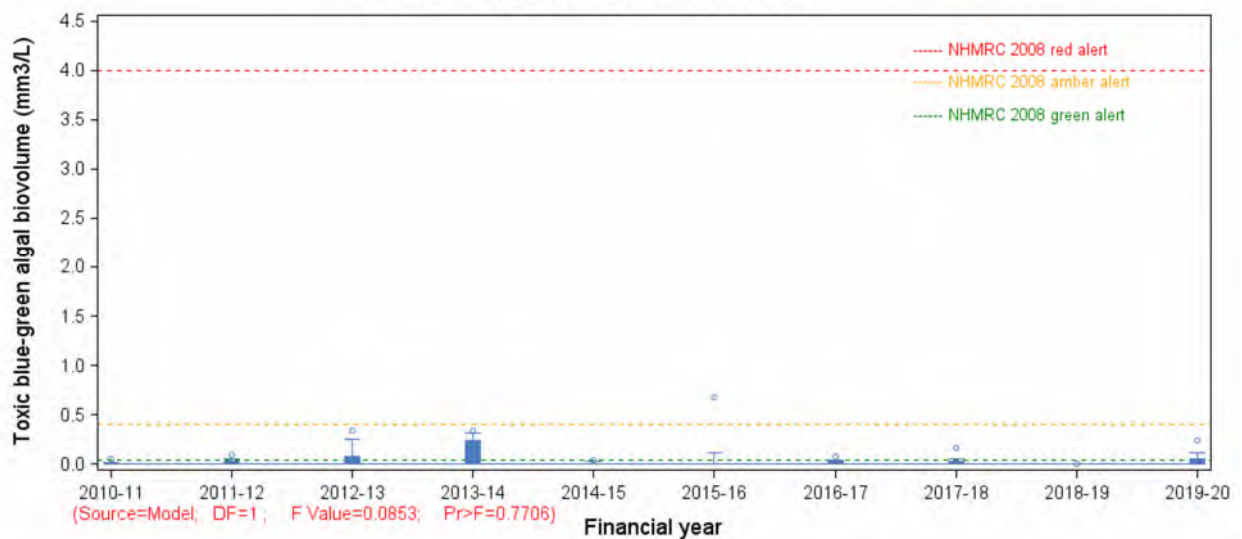
N35: Hawkesbury River at Wilberforce



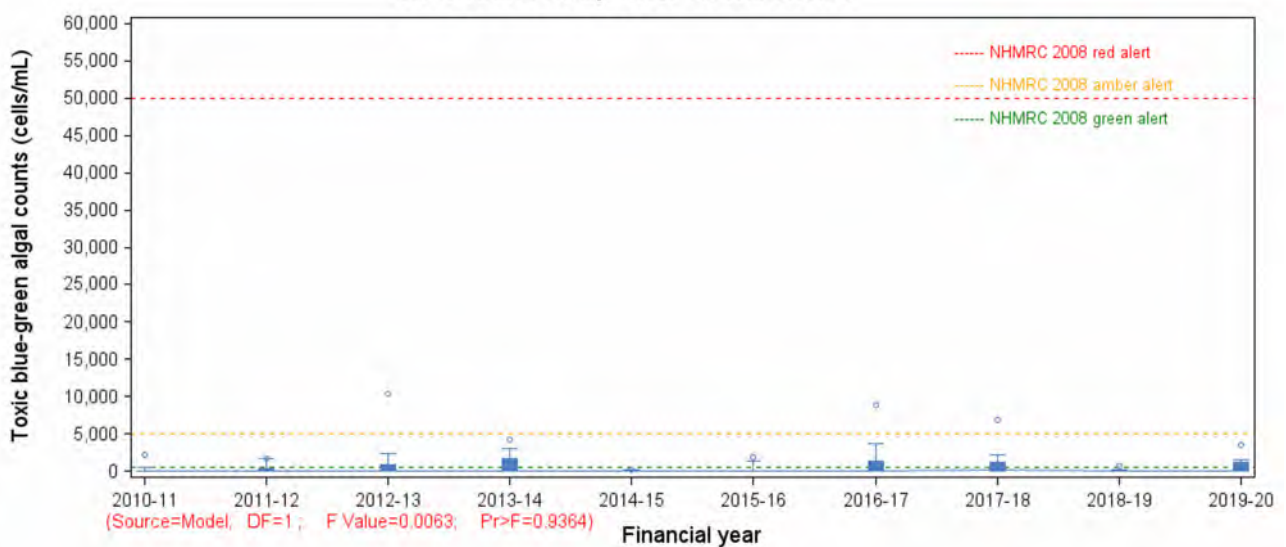
N35: Hawkesbury River at Wilberforce

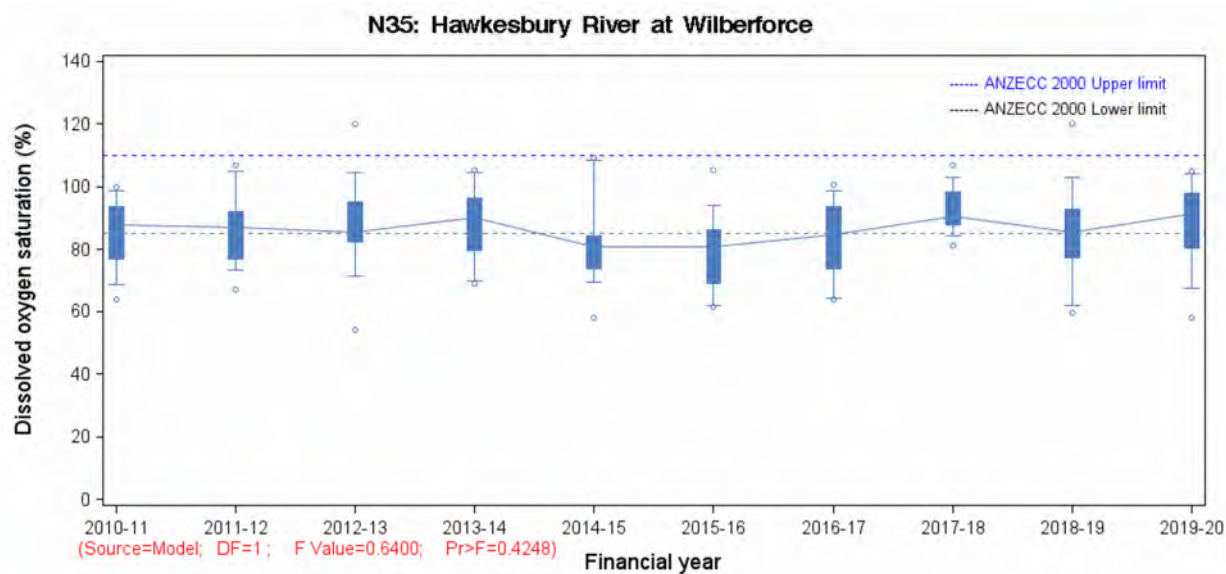
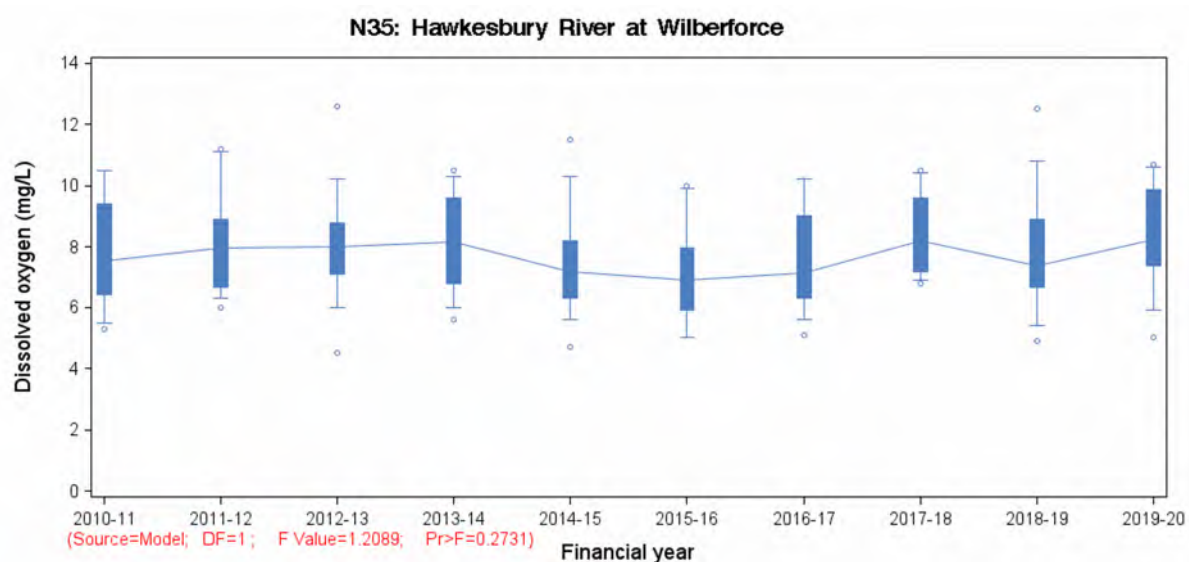
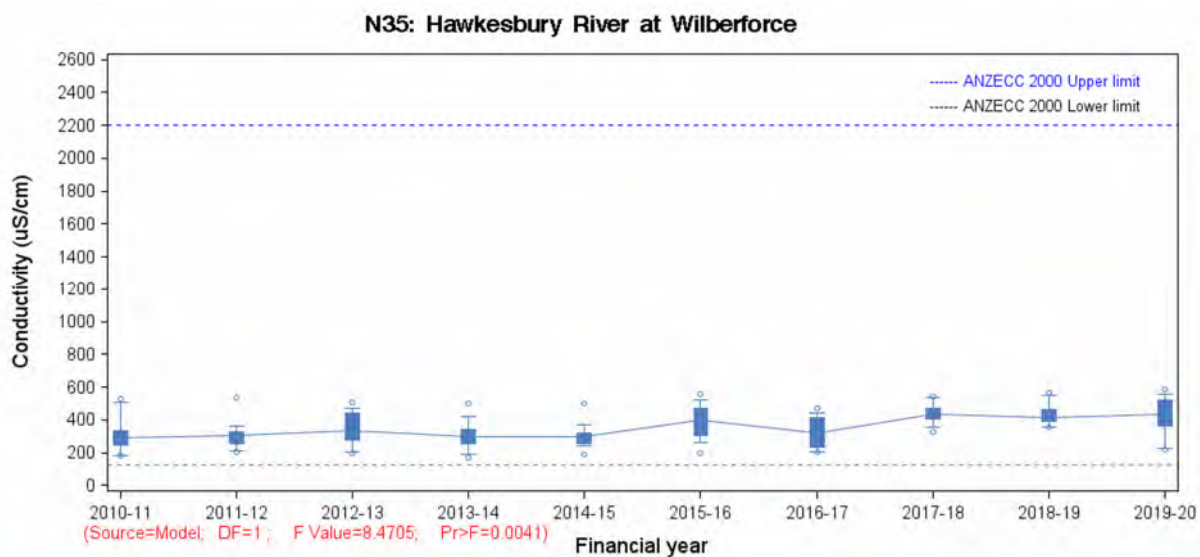


N35: Hawkesbury River at Wilberforce

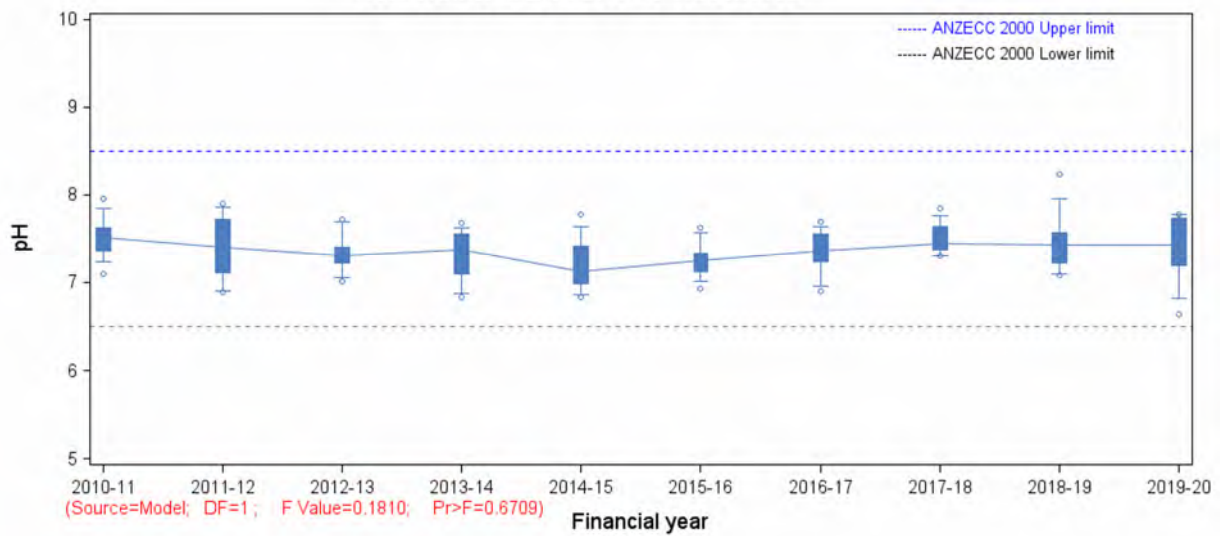


N35: Hawkesbury River at Wilberforce

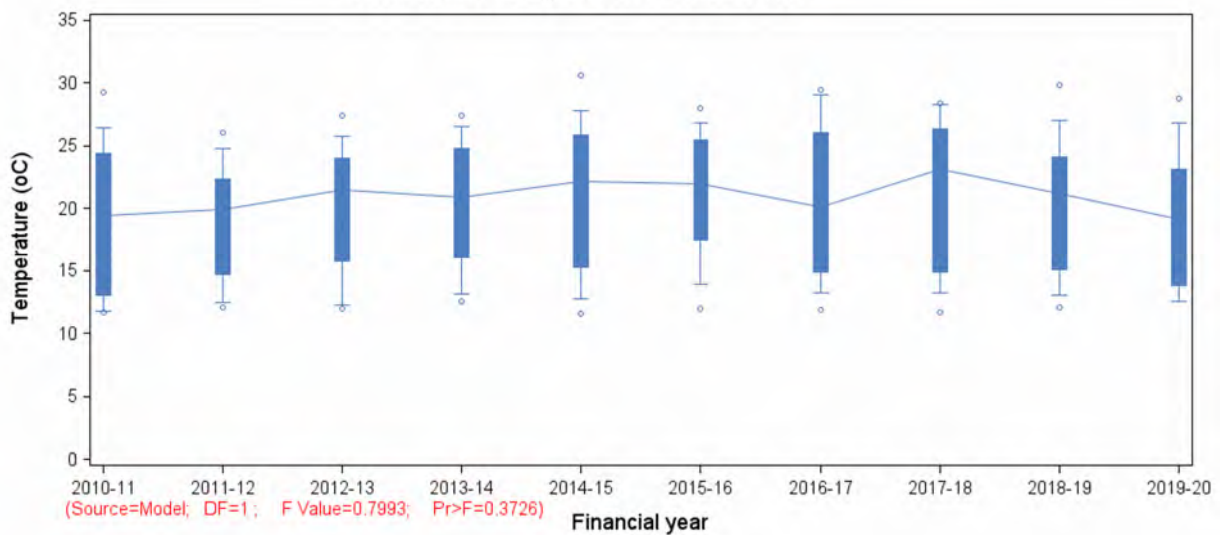




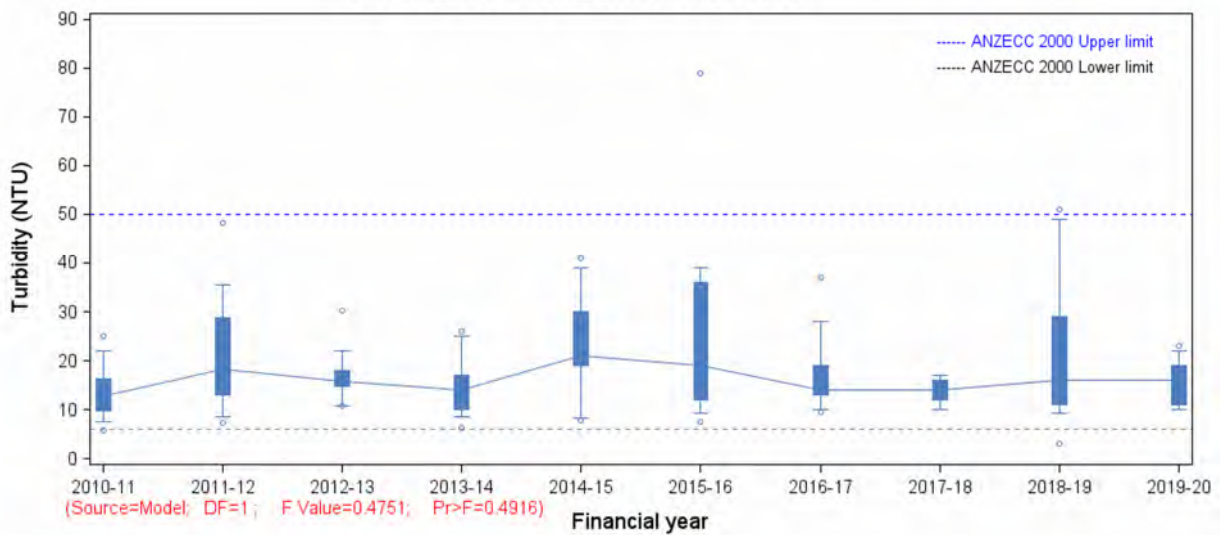
N35: Hawkesbury River at Wilberforce



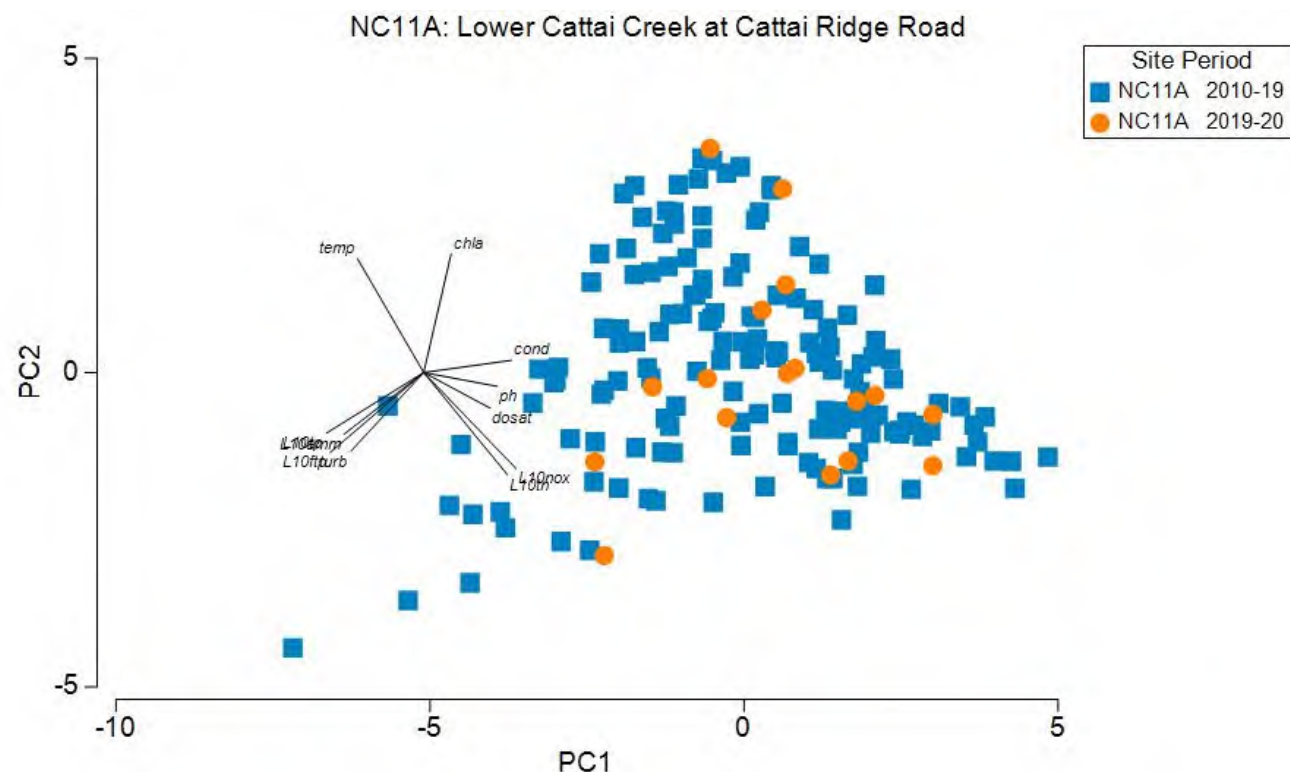
N35: Hawkesbury River at Wilberforce



N35: Hawkesbury River at Wilberforce

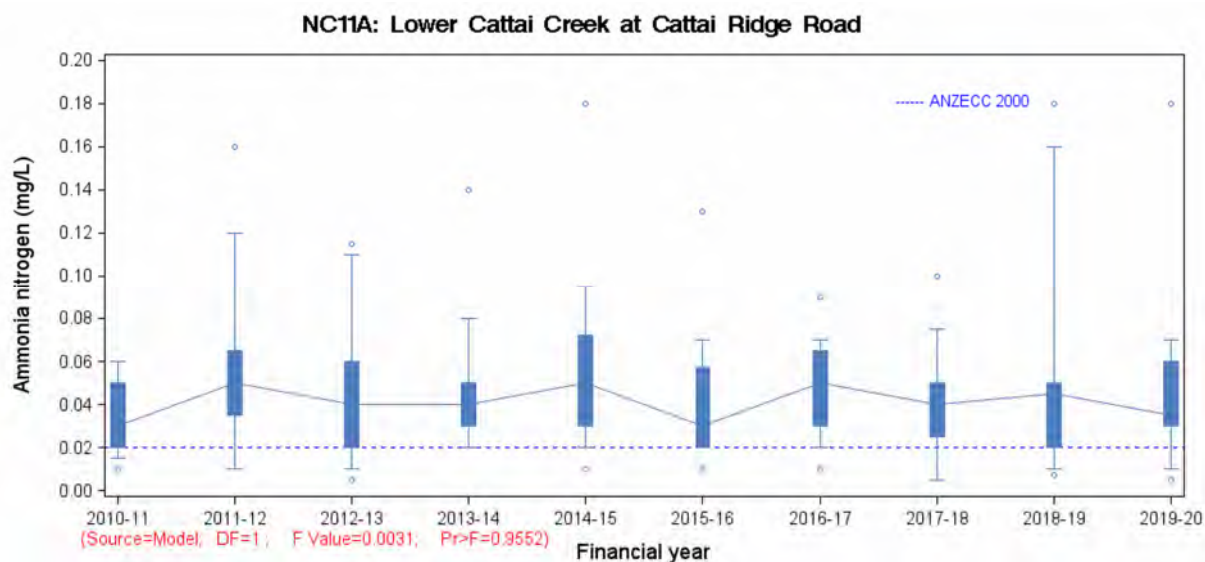


NC11A: Lower Cattai Creek at Cattai Ridge Road

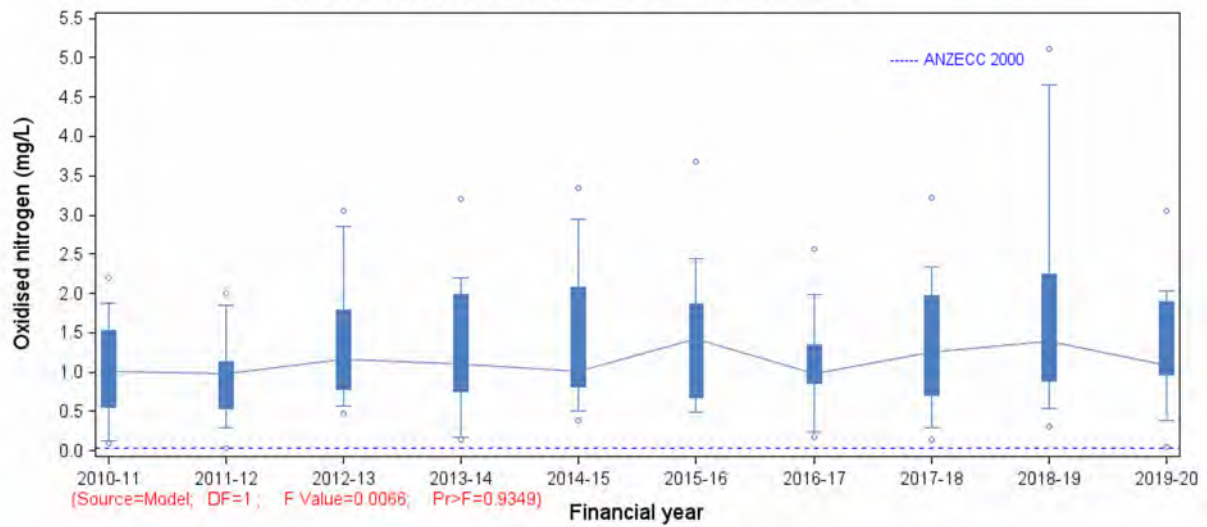


The ordination plot from Principal Components Analysis suggested water quality of the Lower Cattai Creek at Cattai Ridge Road in 2019-20 had similar variability to that recorded in the period 2010 to 2019.

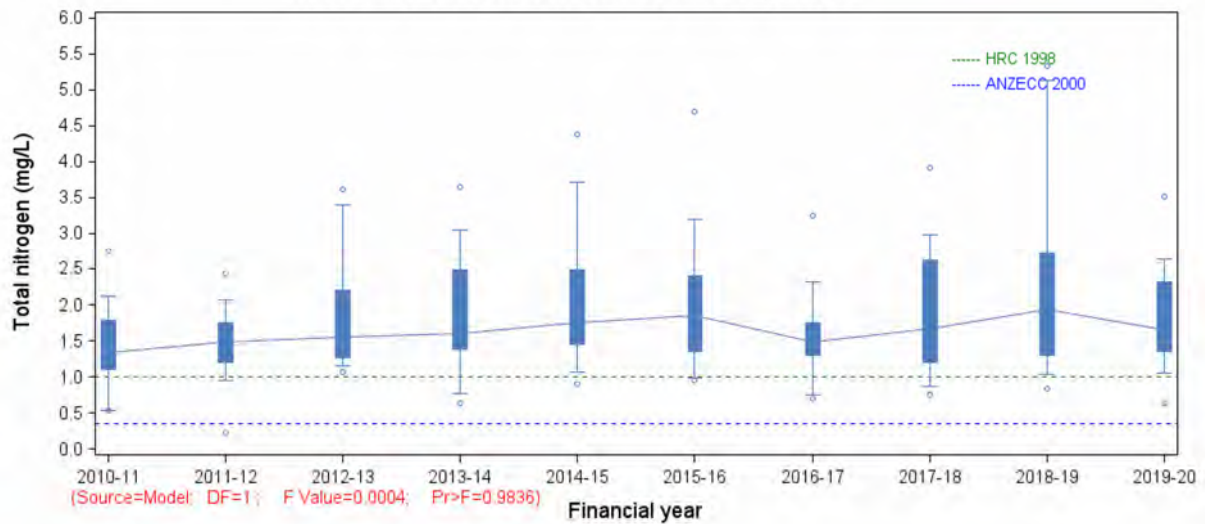
Nutrients, chlorophyll-a and algae



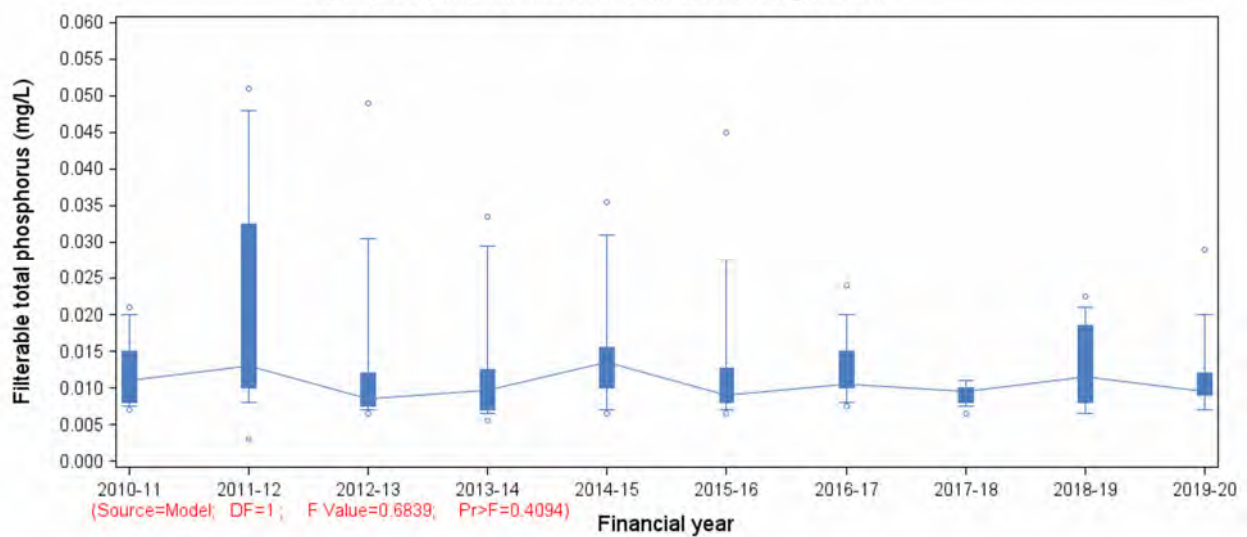
NC11A: Lower Cattai Creek at Cattai Ridge Road



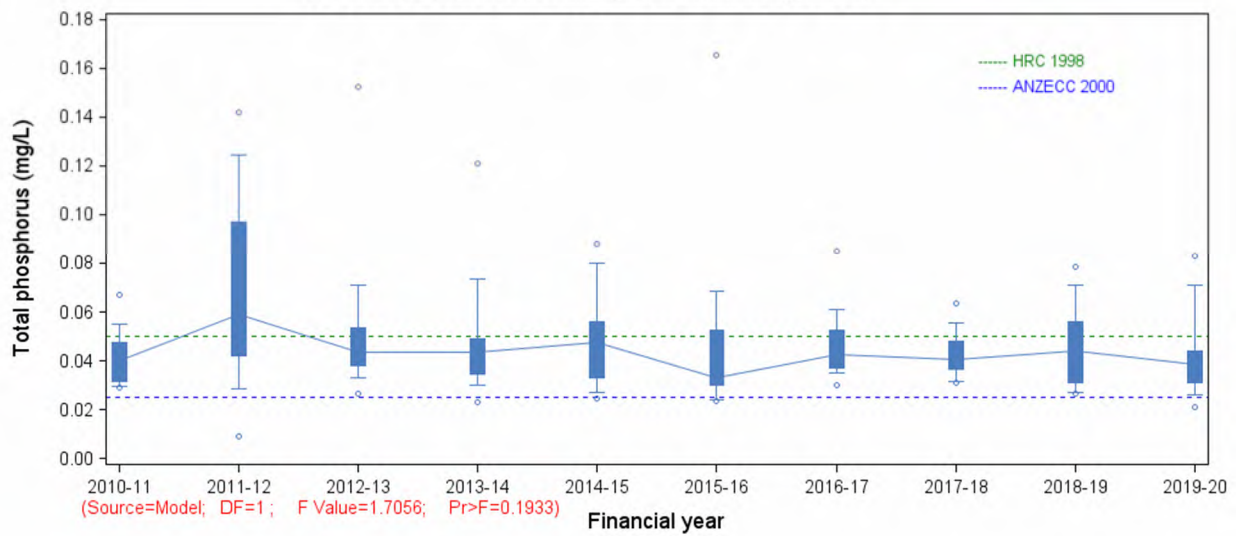
NC11A: Lower Cattai Creek at Cattai Ridge Road



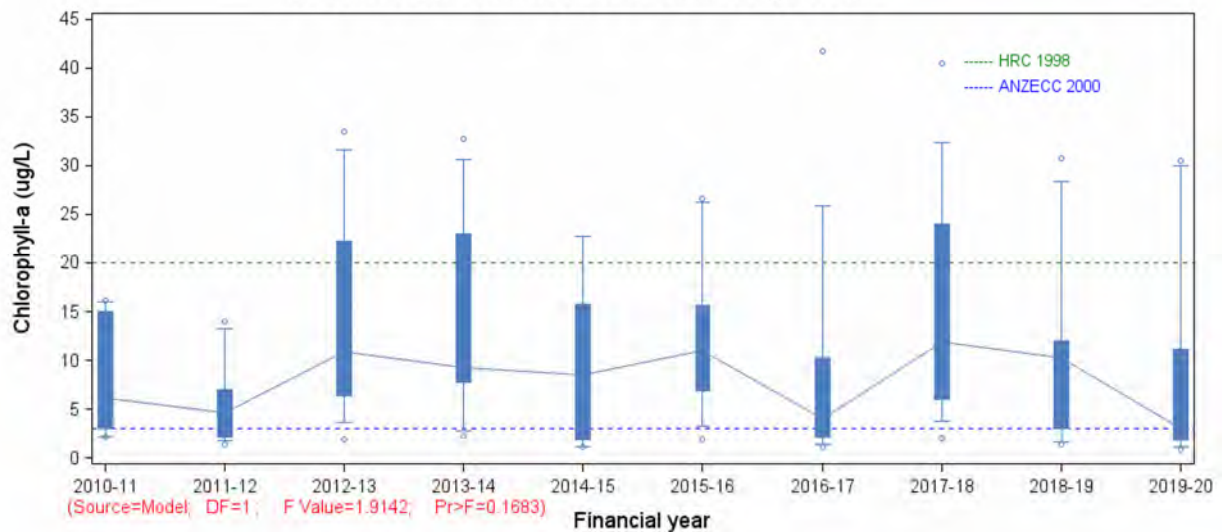
NC11A: Lower Cattai Creek at Cattai Ridge Road



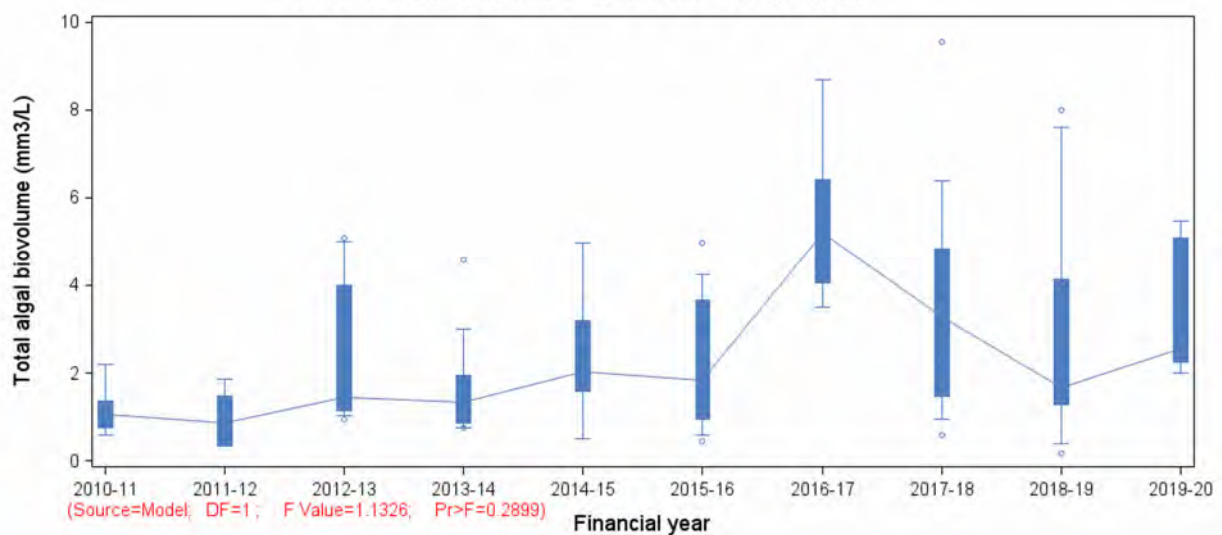
NC11A: Lower Cattai Creek at Cattai Ridge Road



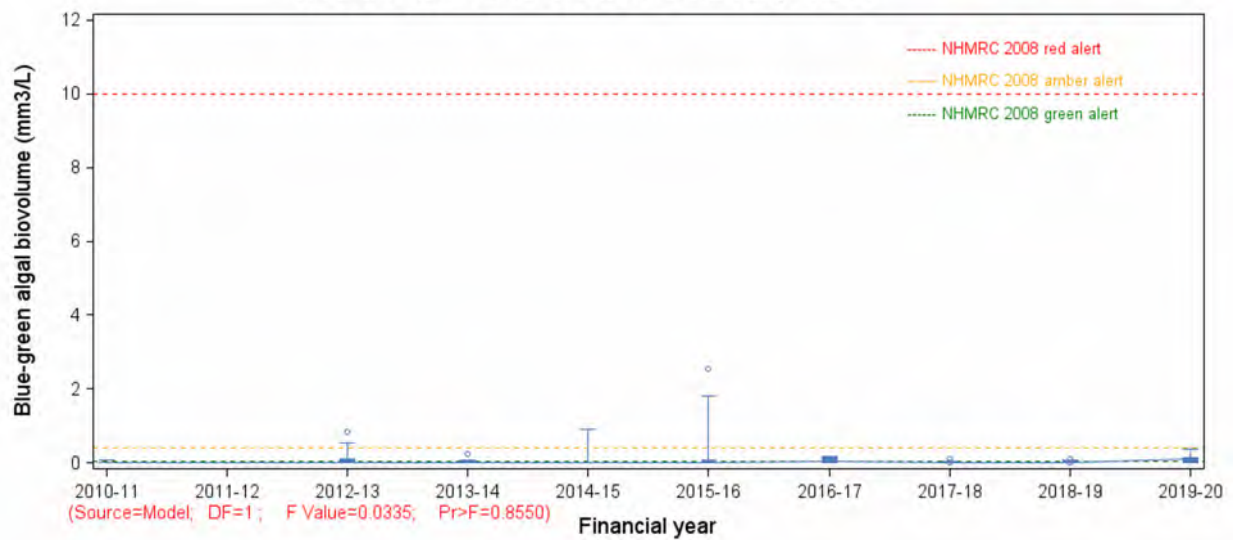
NC11A: Lower Cattai Creek at Cattai Ridge Road



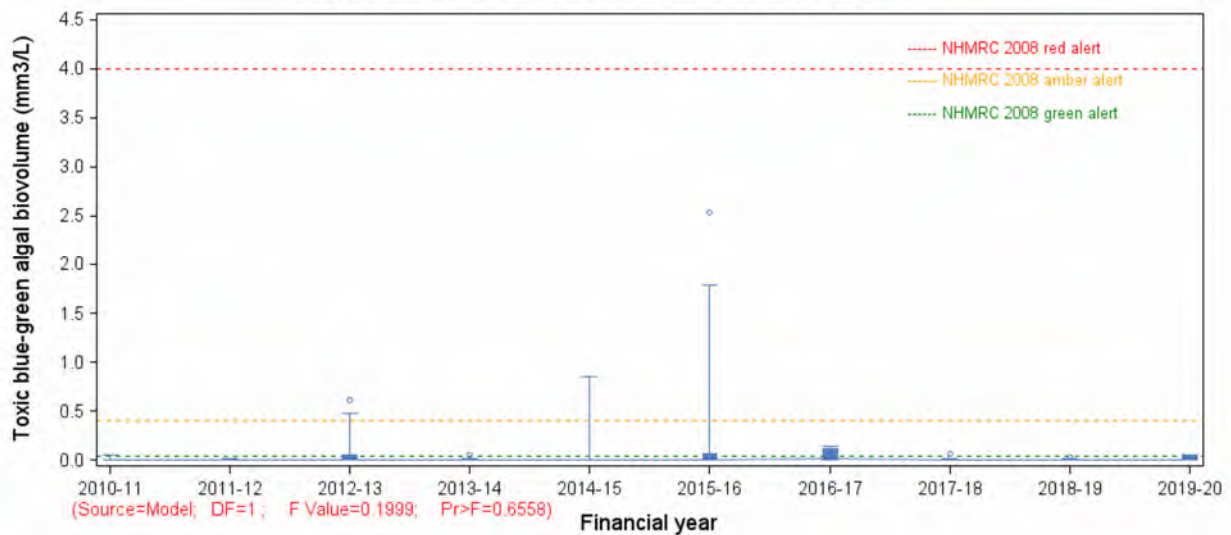
NC11A: Lower Cattai Creek at Cattai Ridge Road



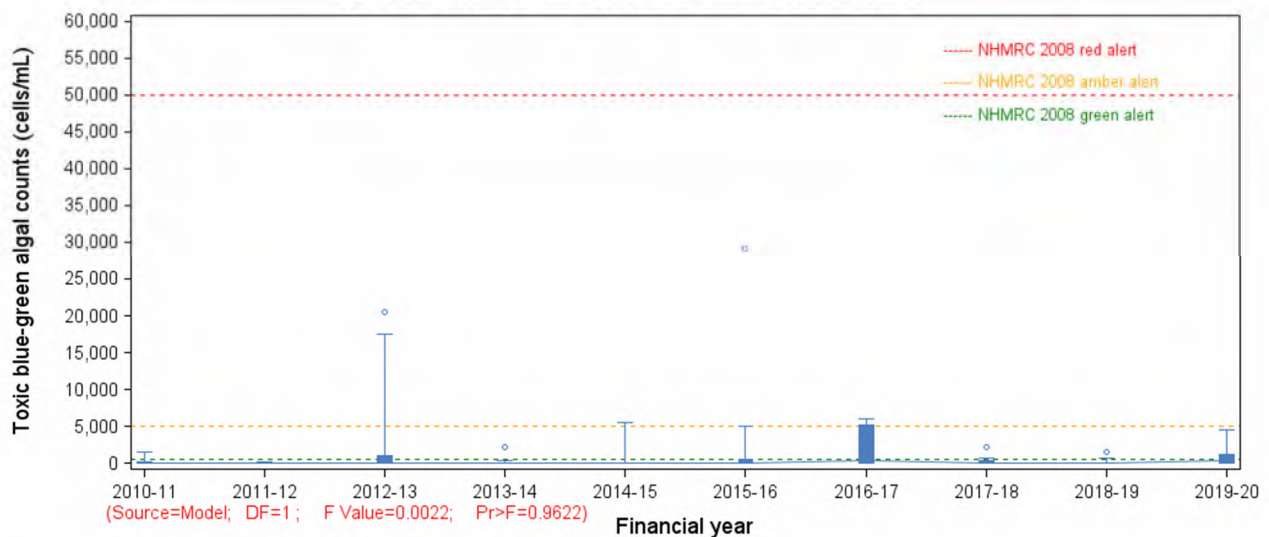
NC11A: Lower Cattai Creek at Cattai Ridge Road



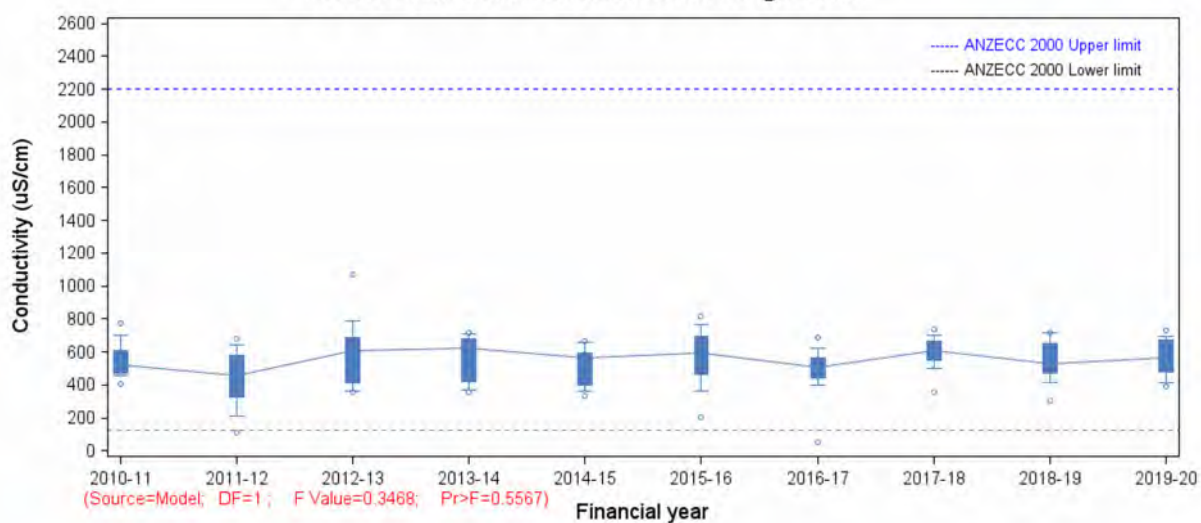
NC11A: Lower Cattai Creek at Cattai Ridge Road



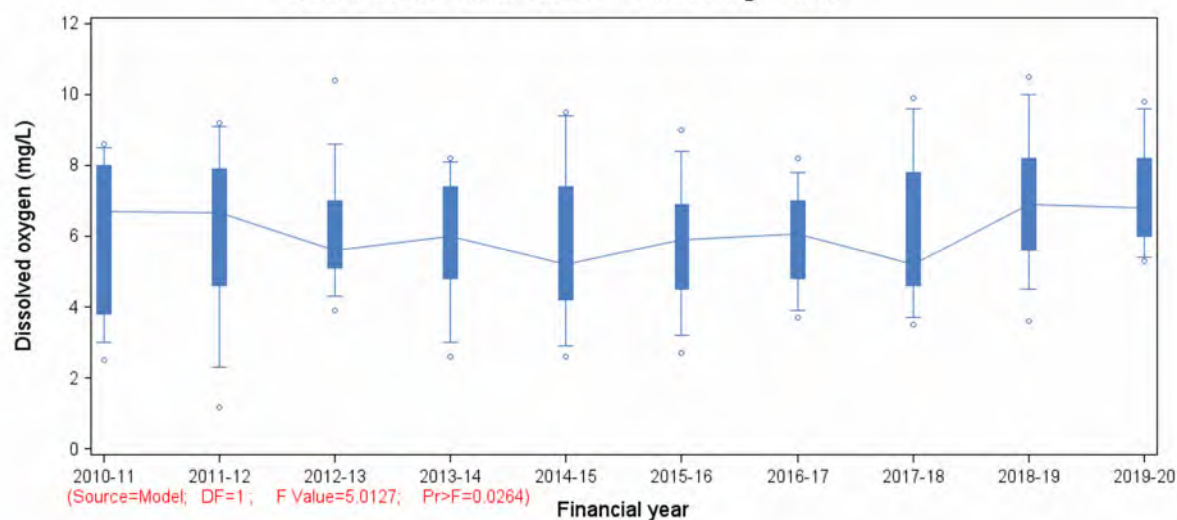
NC11A: Lower Cattai Creek at Cattai Ridge Road



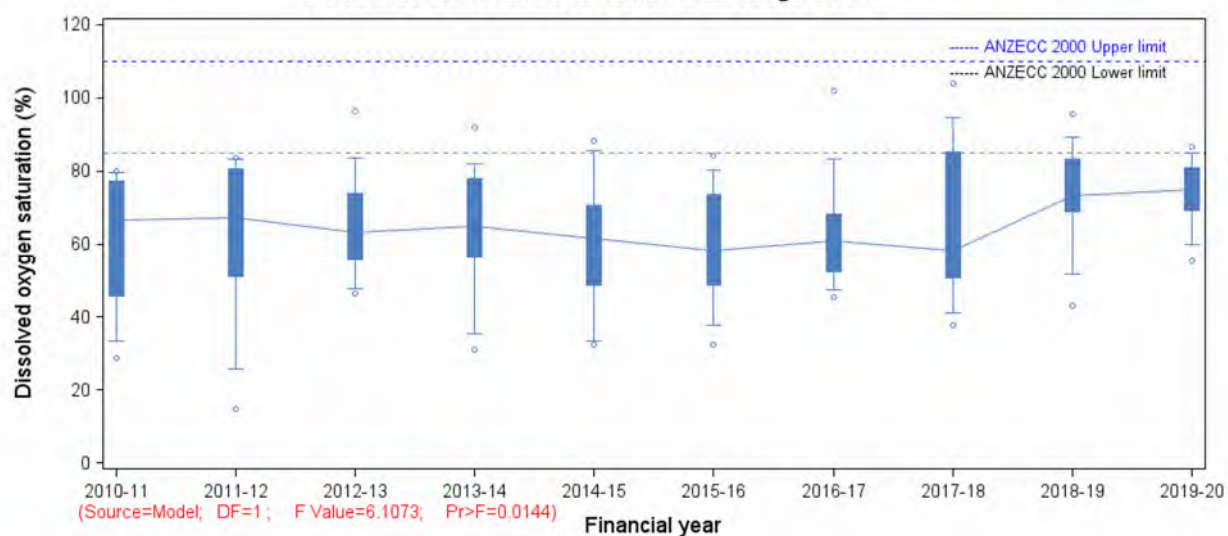
NC11A: Lower Cattai Creek at Cattai Ridge Road



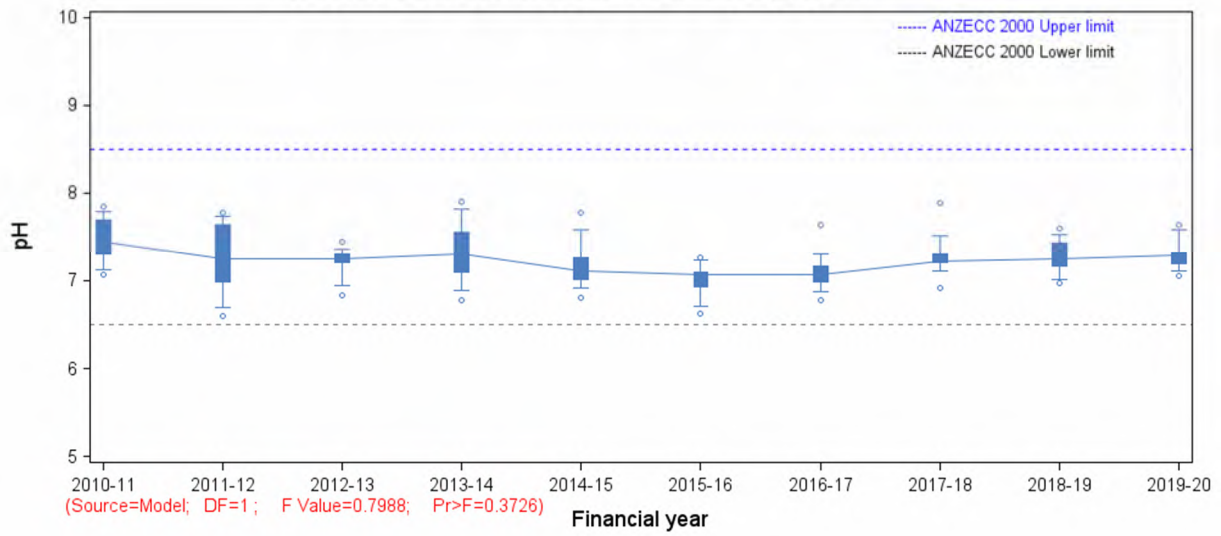
NC11A: Lower Cattai Creek at Cattai Ridge Road



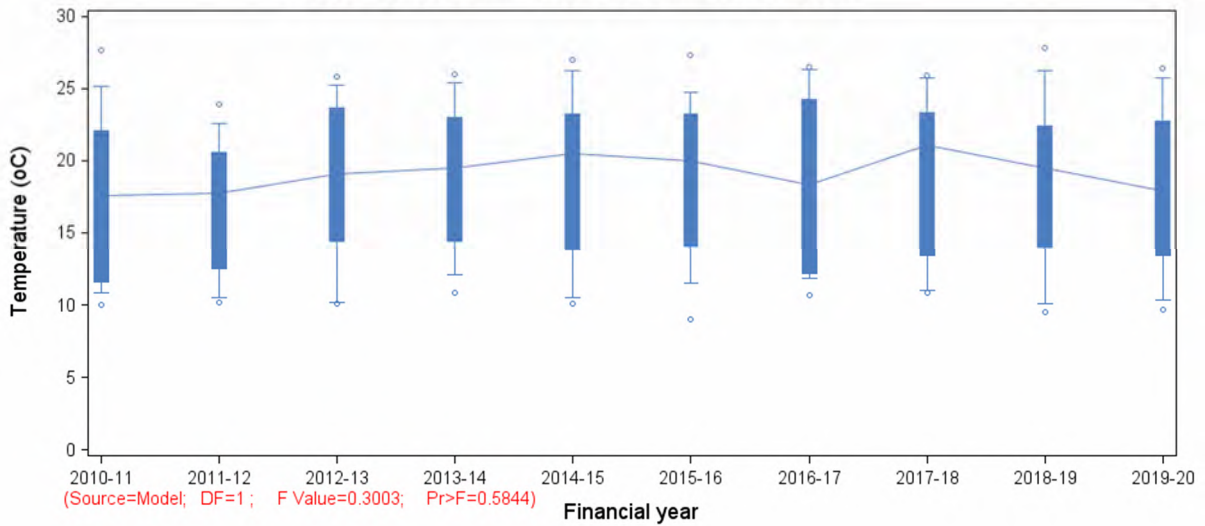
NC11A: Lower Cattai Creek at Cattai Ridge Road



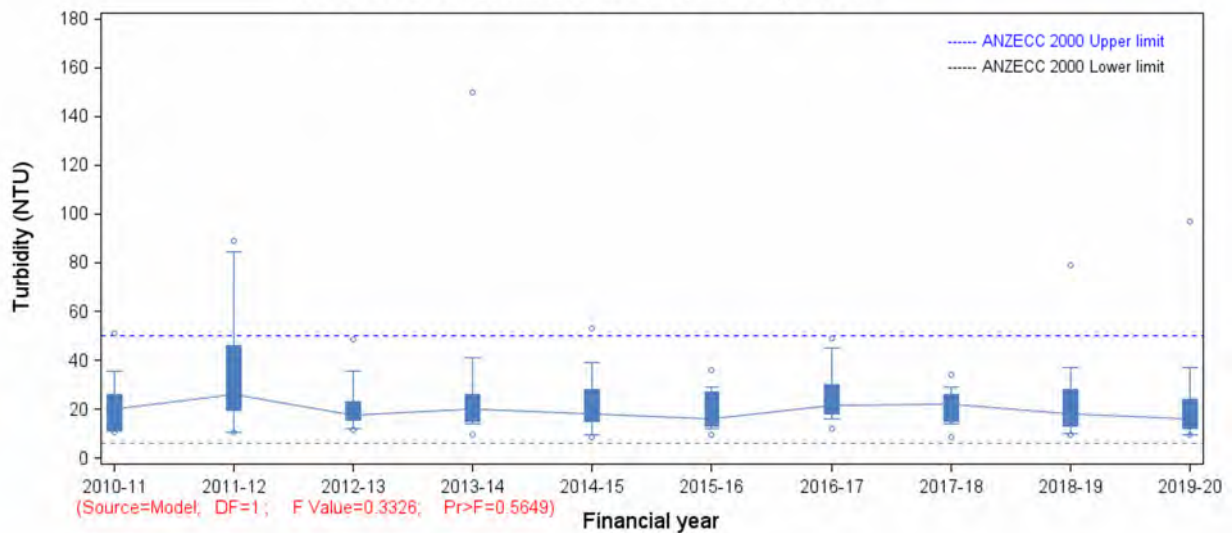
NC11A: Lower Cattai Creek at Cattai Ridge Road



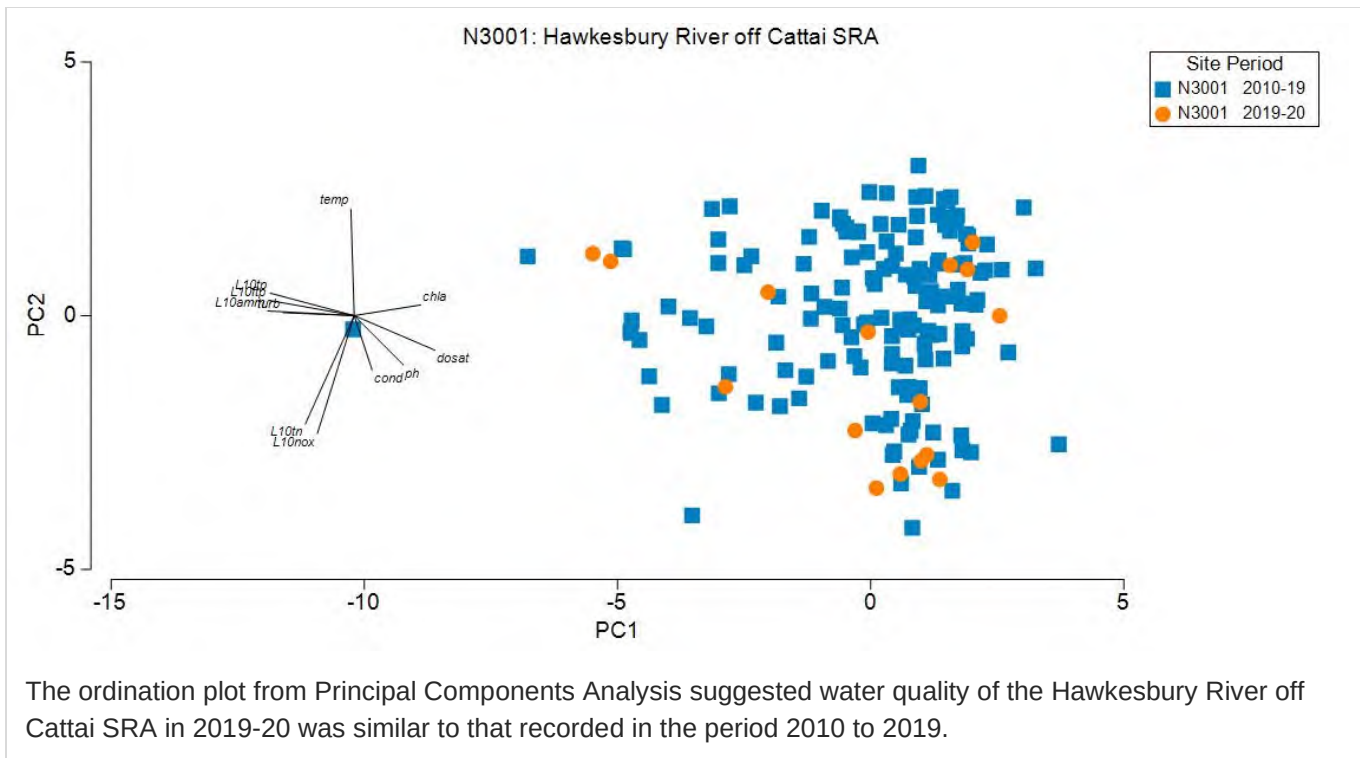
NC11A: Lower Cattai Creek at Cattai Ridge Road



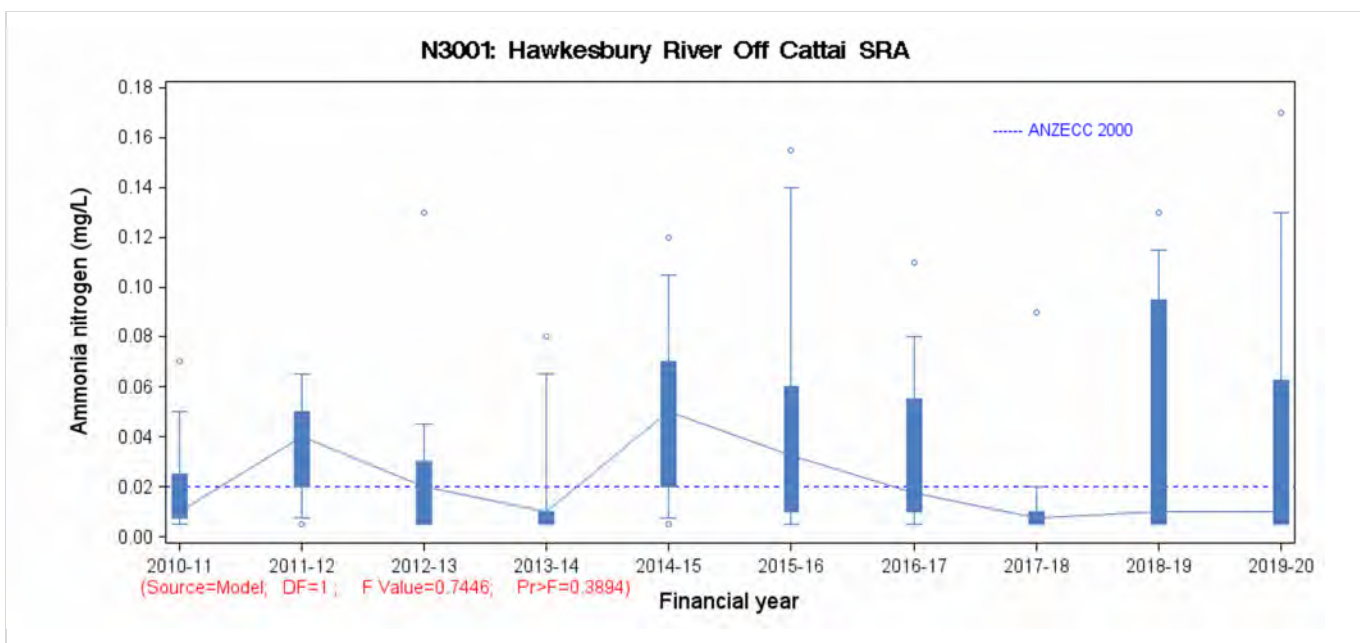
NC11A: Lower Cattai Creek at Cattai Ridge Road

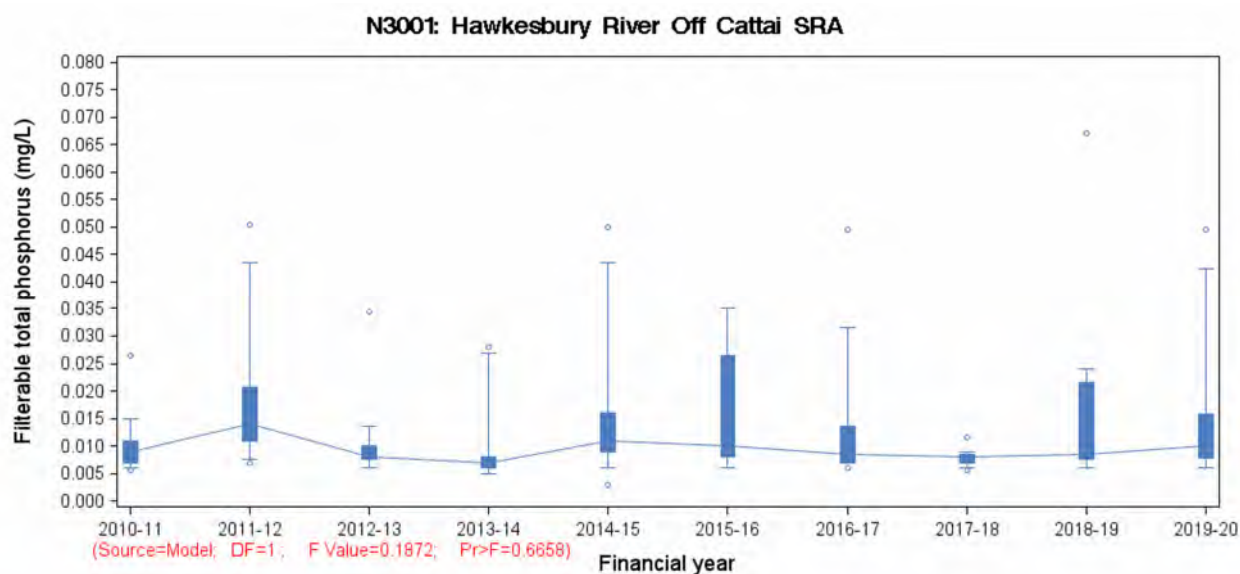
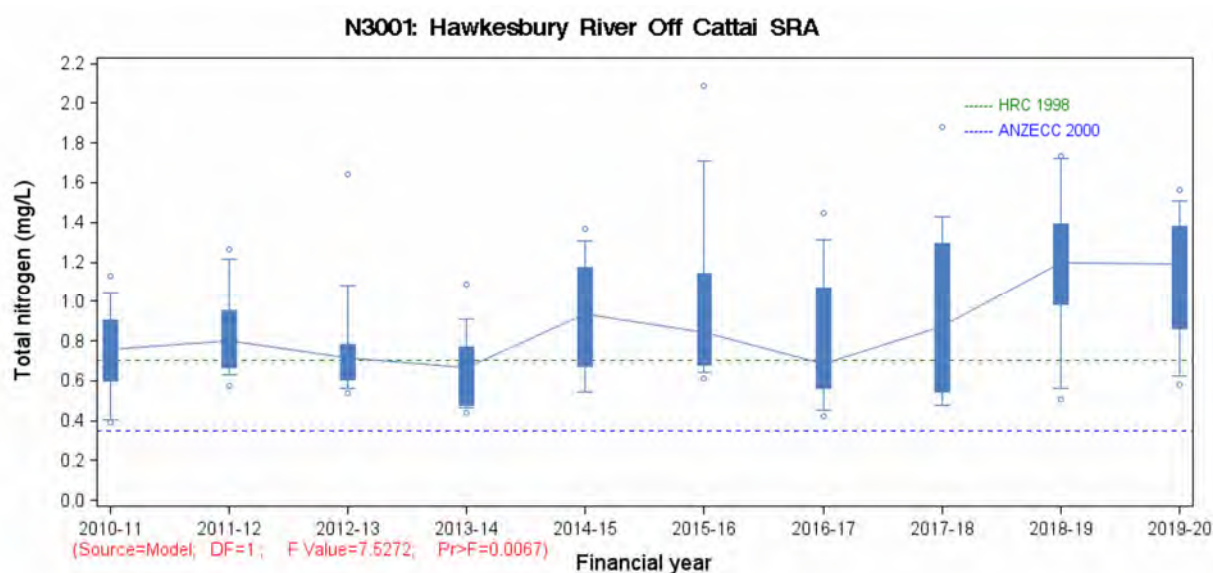
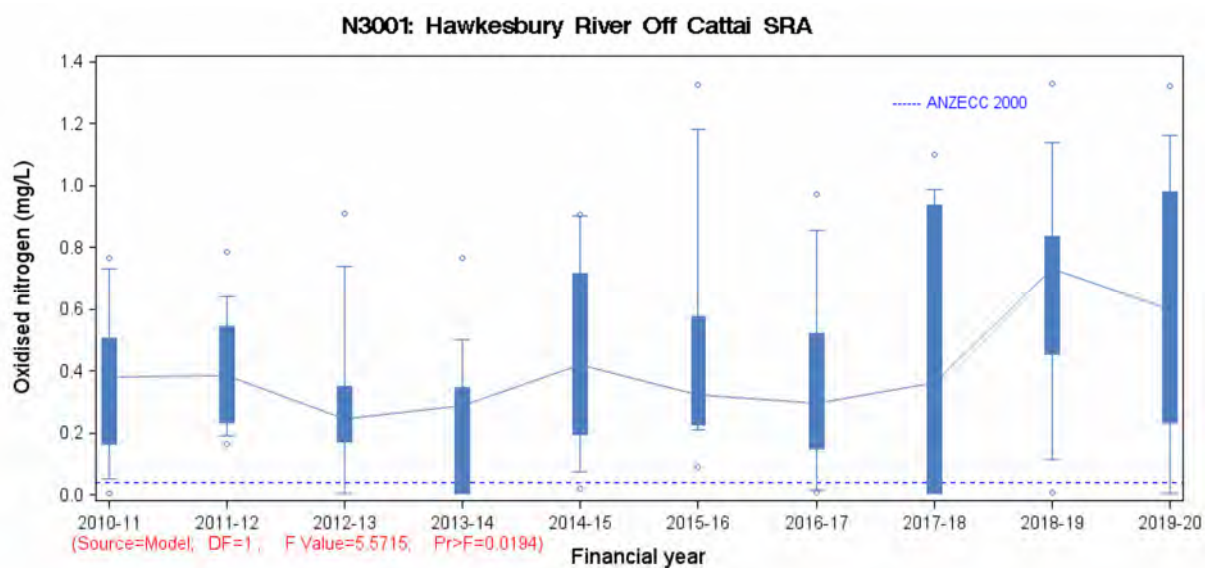


N3001: Hawkesbury River off Cattai SRA

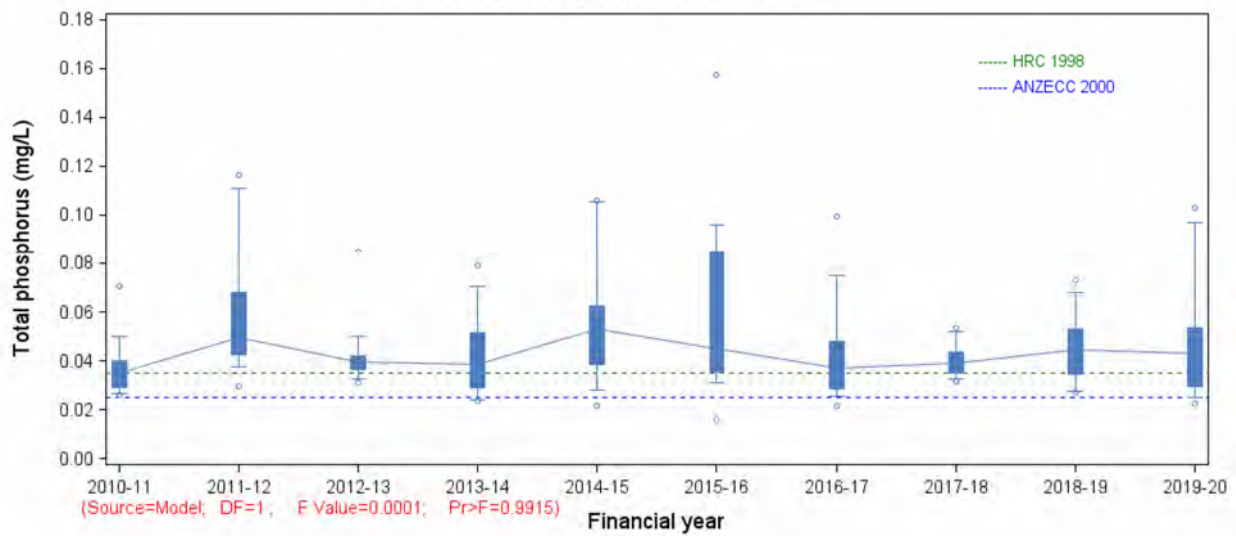


Nutrients, chlorophyll-a and algae

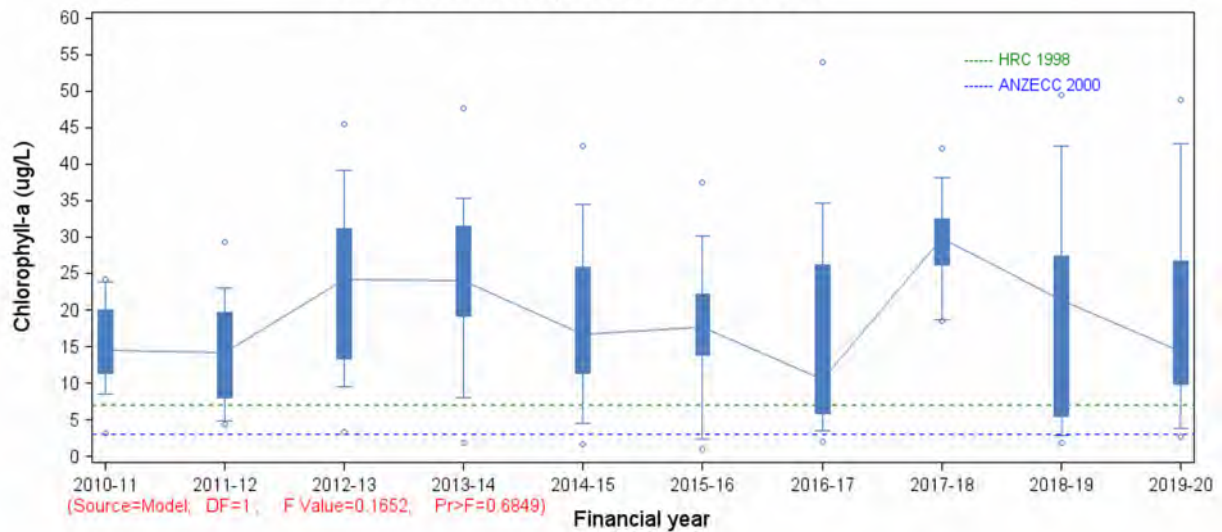




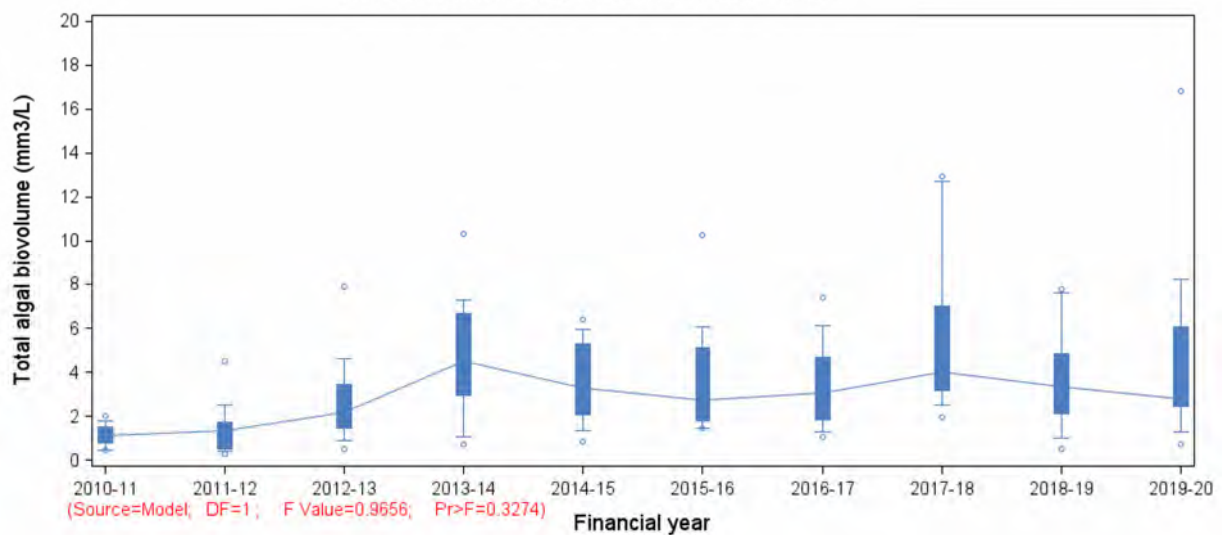
N3001: Hawkesbury River Off Cattai SRA



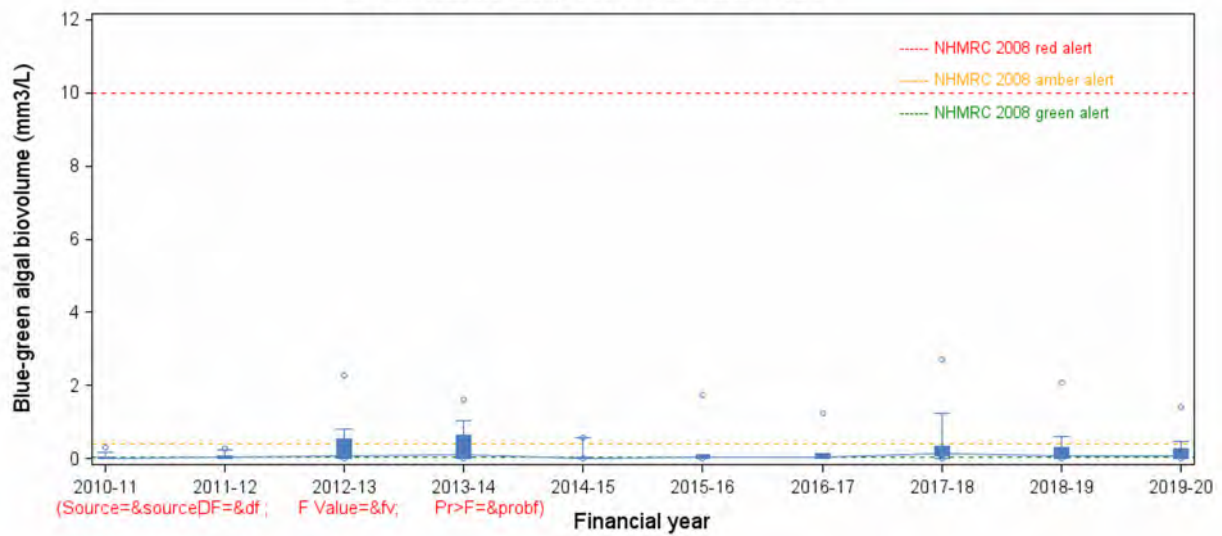
N3001: Hawkesbury River Off Cattai SRA



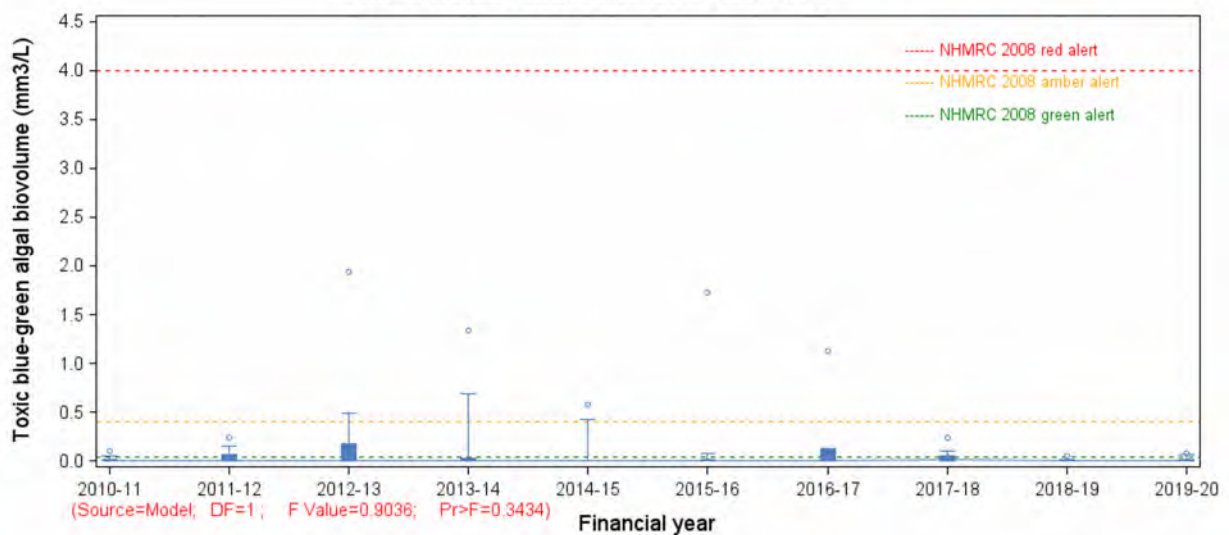
N3001: Hawkesbury River Off Cattai SRA



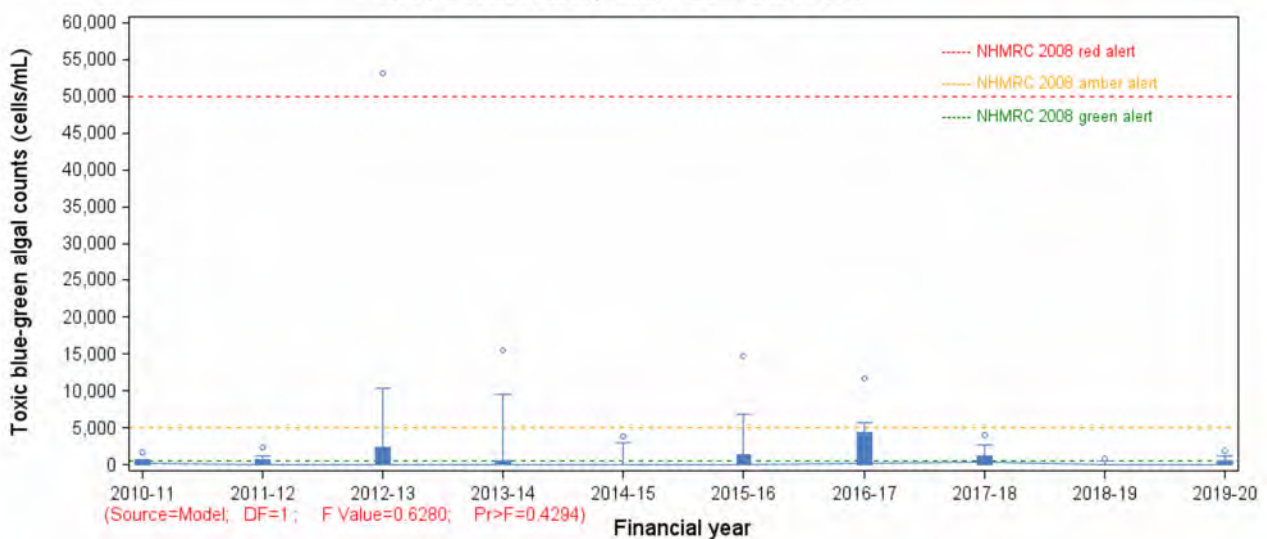
N3001: Hawkesbury River Off Cattai SRA

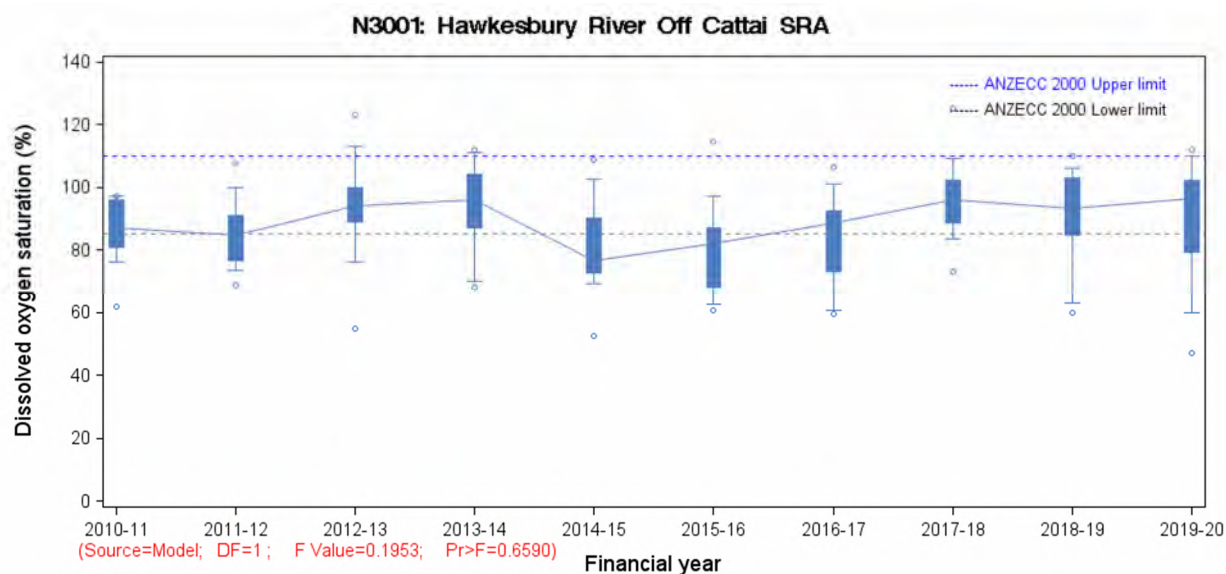
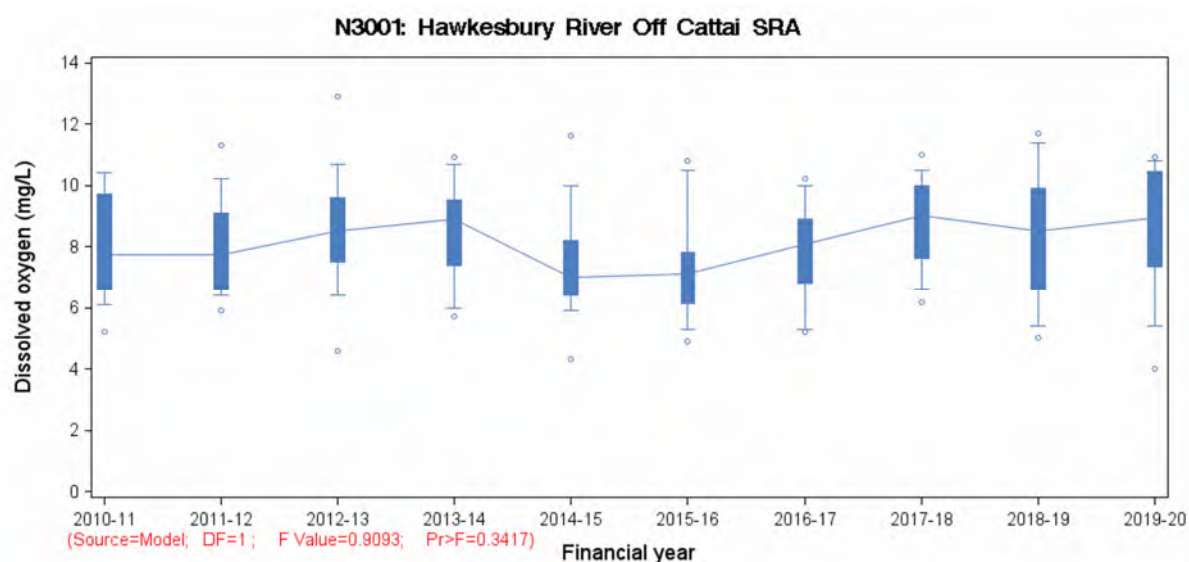
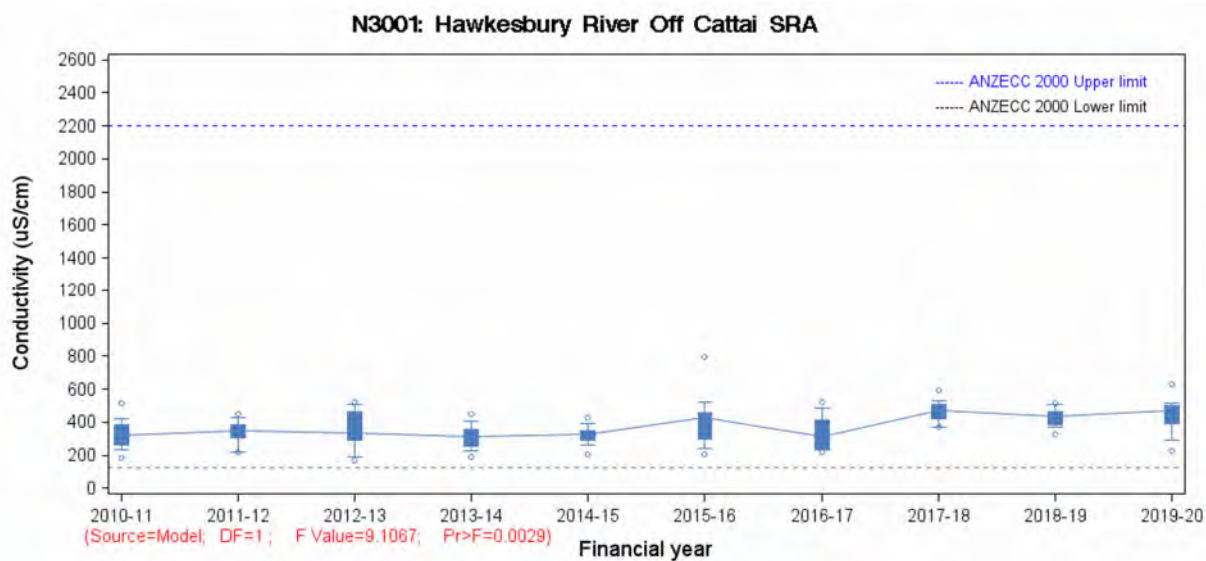


N3001: Hawkesbury River Off Cattai SRA

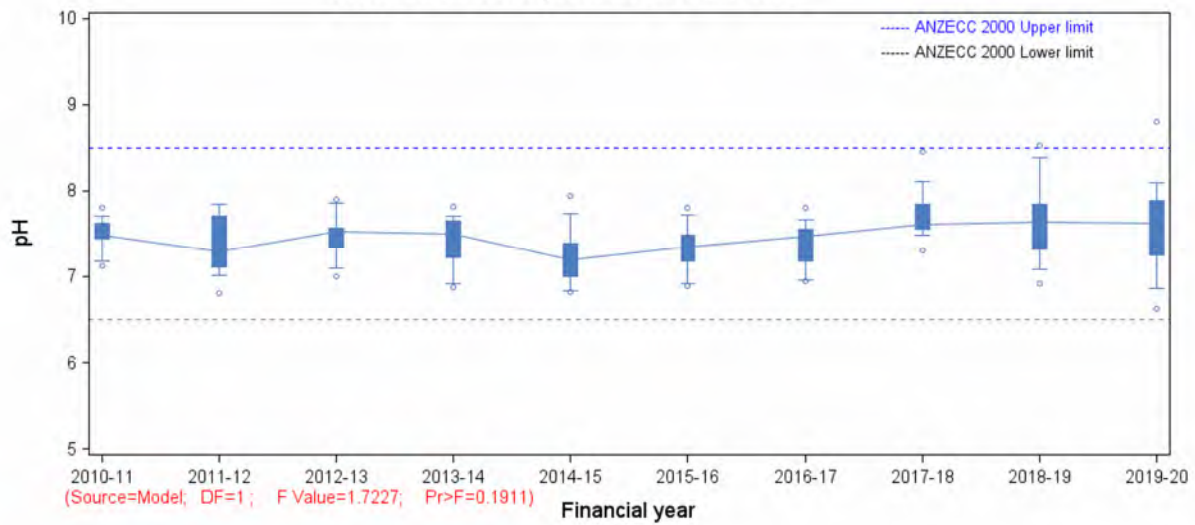


N3001: Hawkesbury River Off Cattai SRA

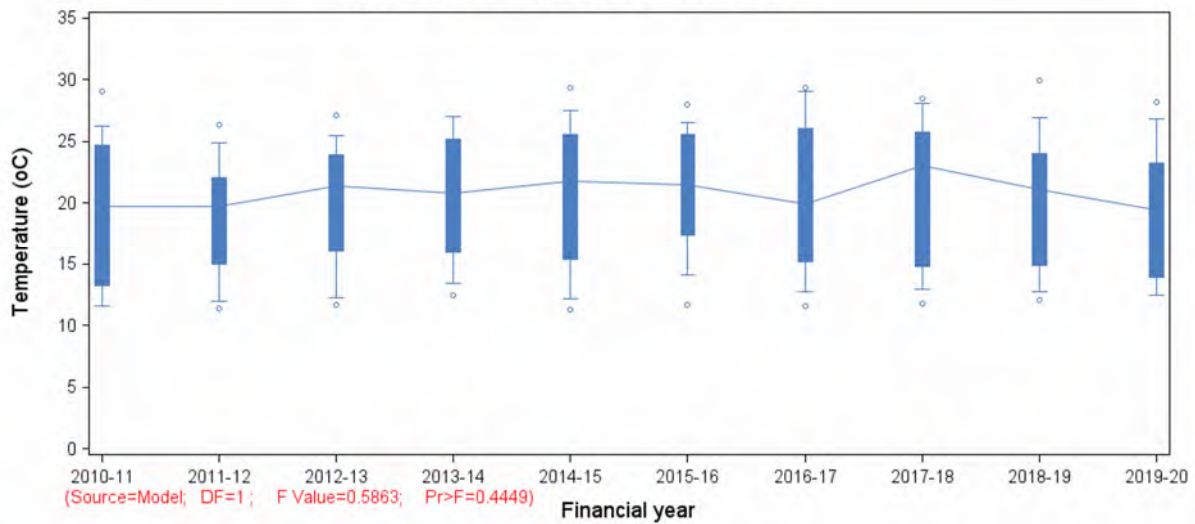




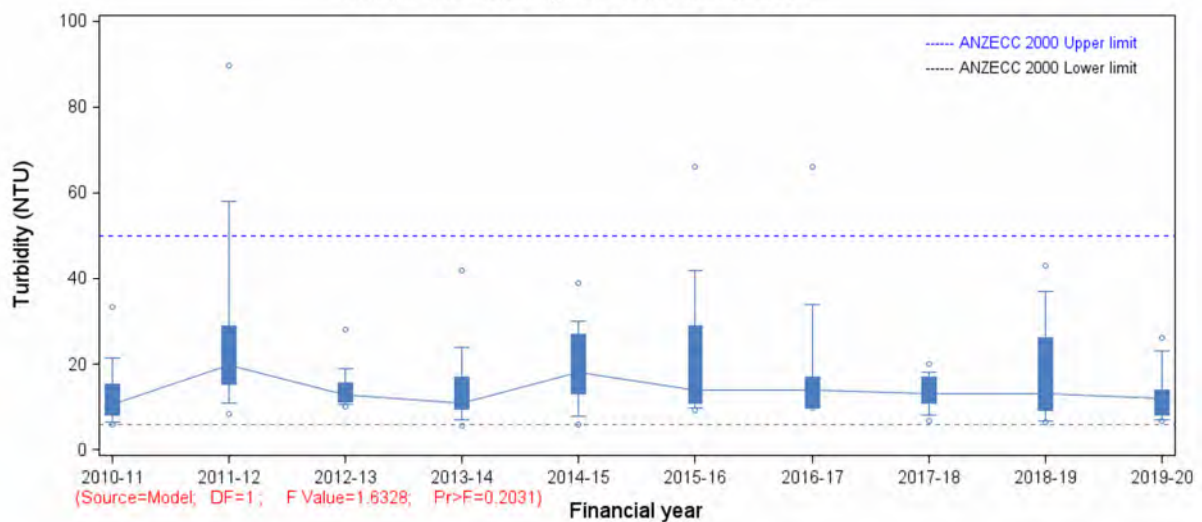
N3001: Hawkesbury River Off Cattai SRA



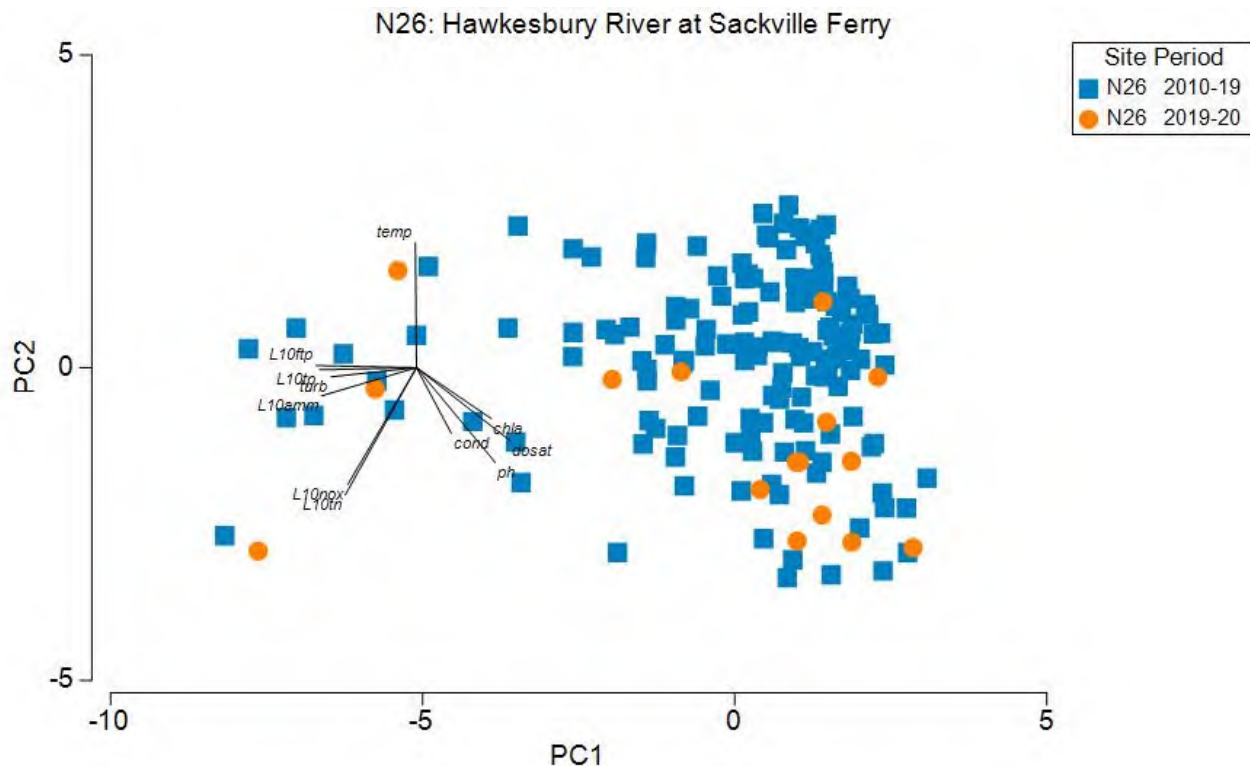
N3001: Hawkesbury River Off Cattai SRA



N3001: Hawkesbury River Off Cattai SRA

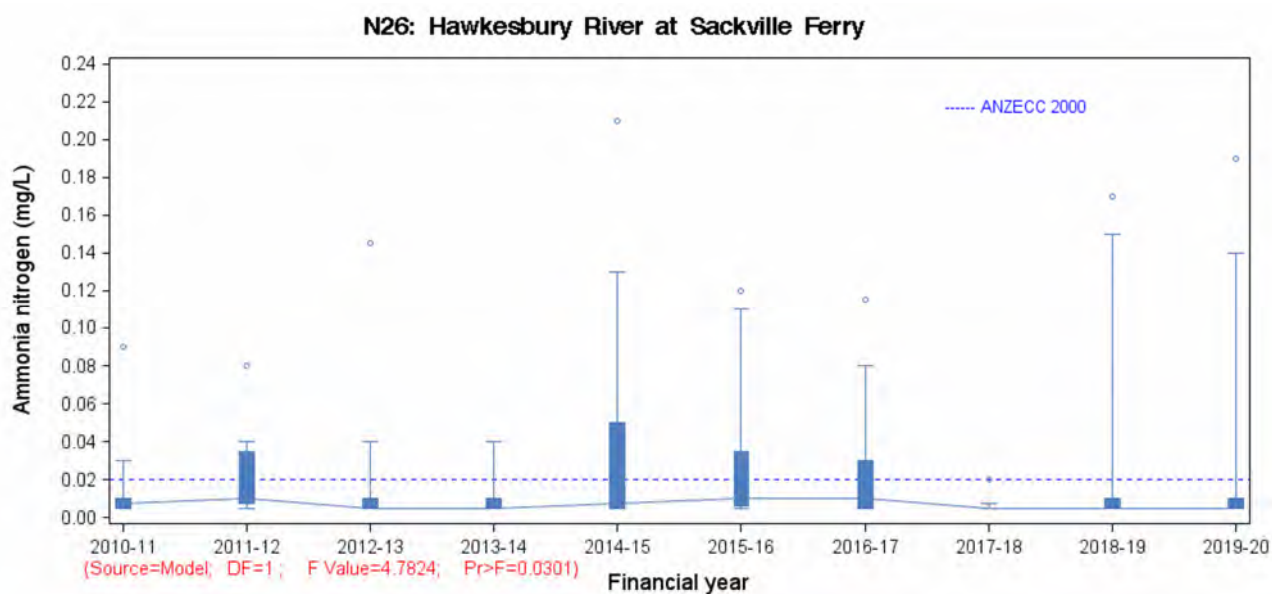


N26: Hawkesbury River at Sackville Ferry

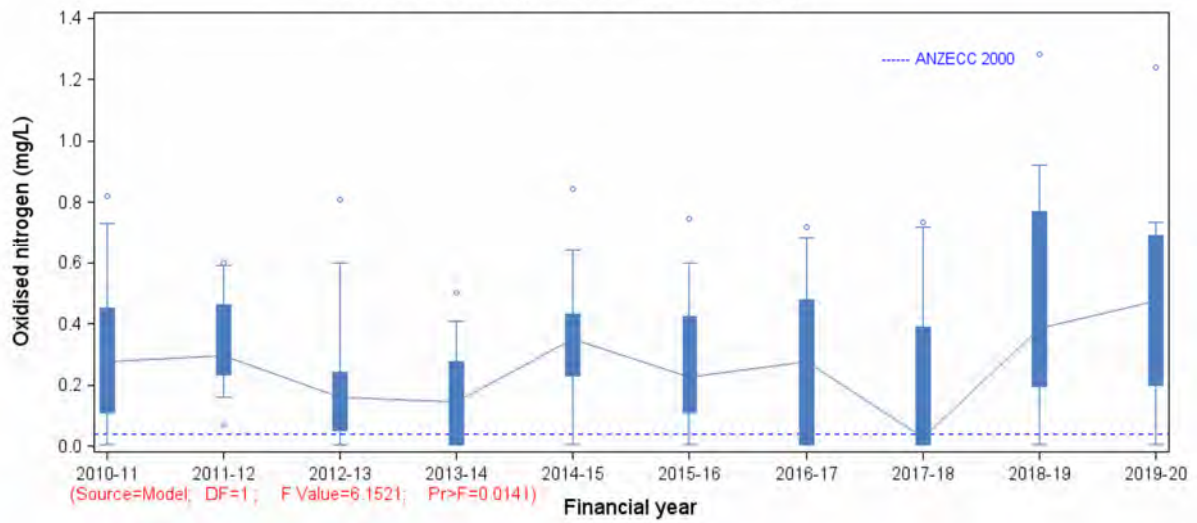


The ordination plot from Principal Components Analysis suggested water quality of the Hawkesbury River at Sackville ferry in 2019-20 was similar to that recorded in the period 2010 to 2019.

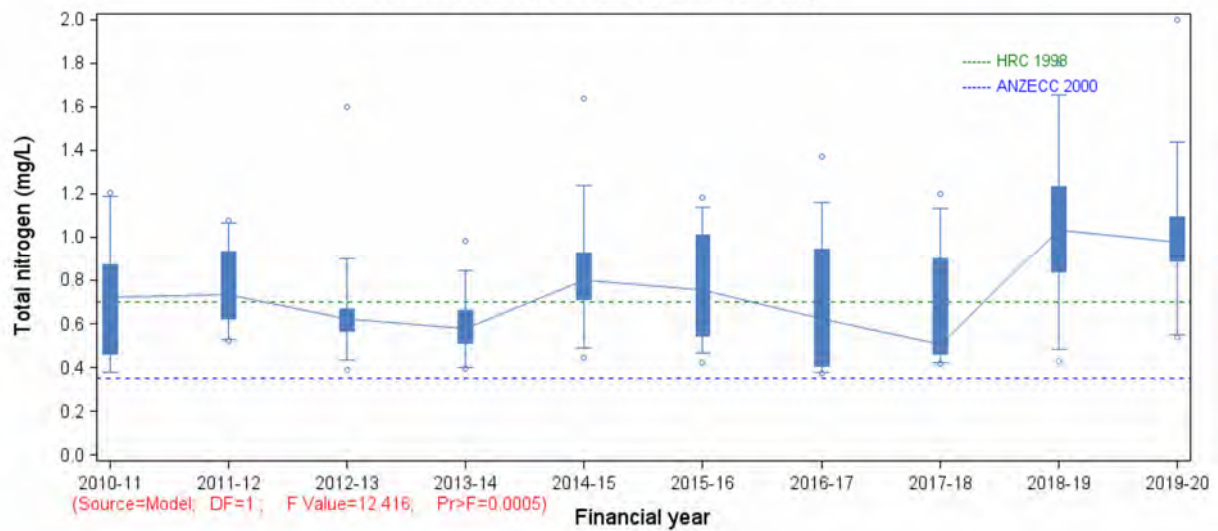
Nutrients, chlorophyll-a and algae



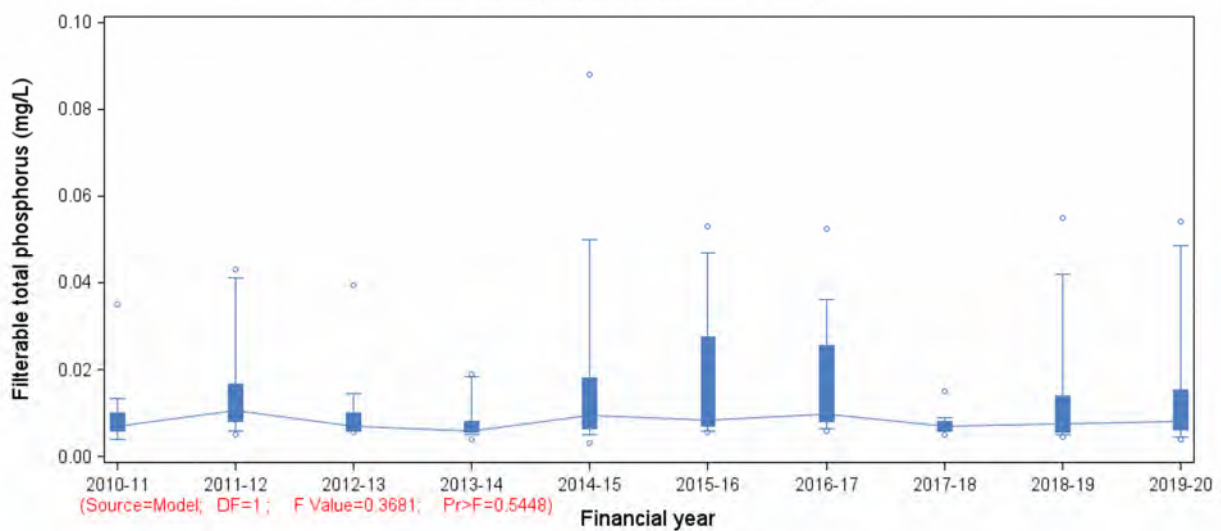
N26: Hawkesbury River at Sackville Ferry



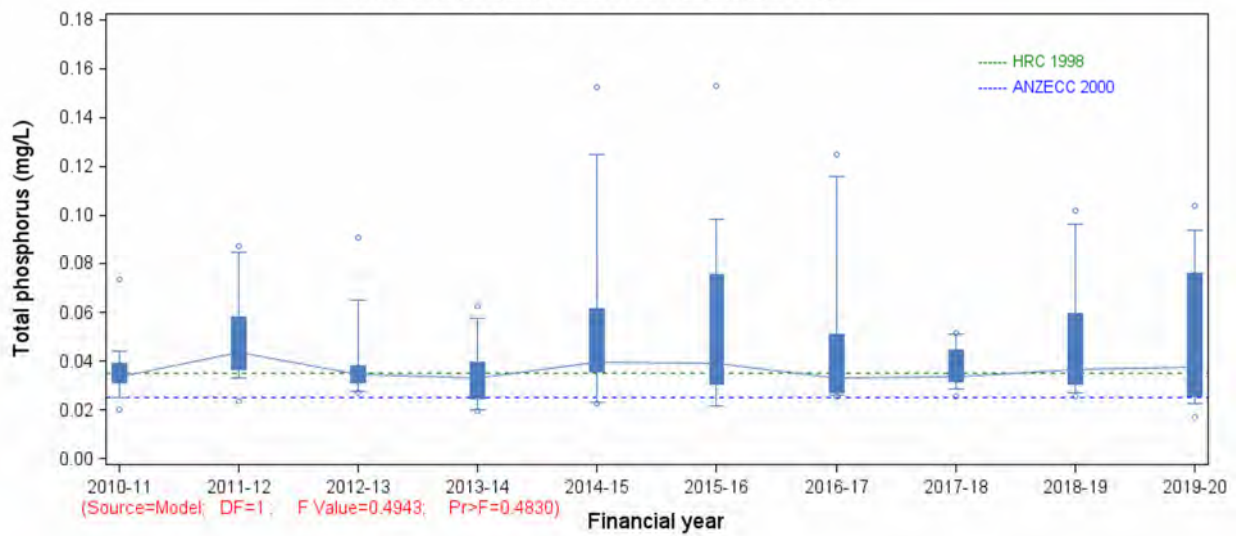
N26: Hawkesbury River at Sackville Ferry



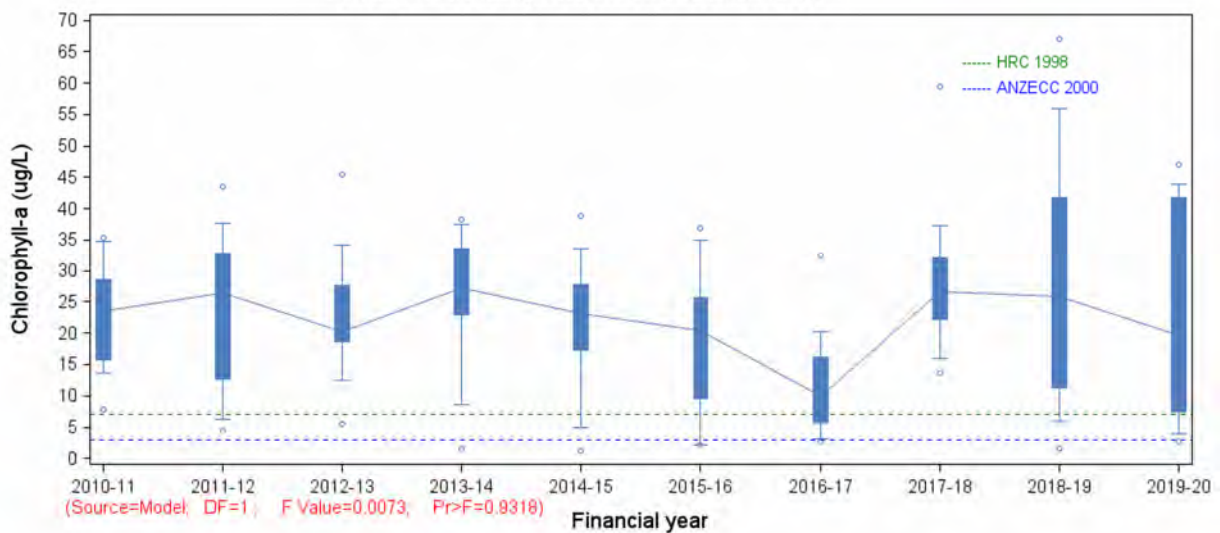
N26: Hawkesbury River at Sackville Ferry



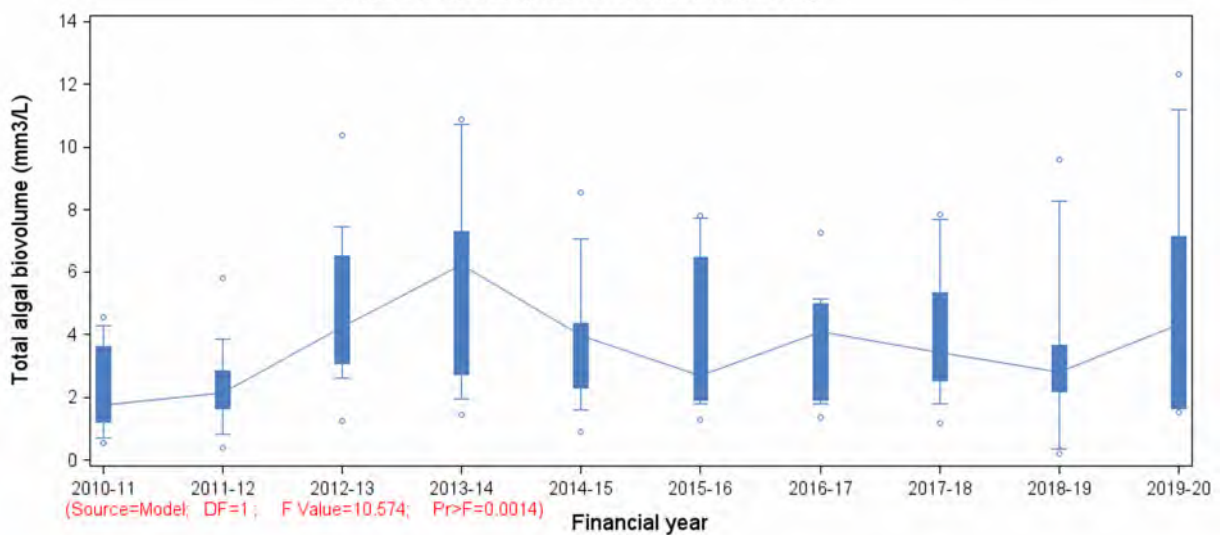
N26: Hawkesbury River at Sackville Ferry



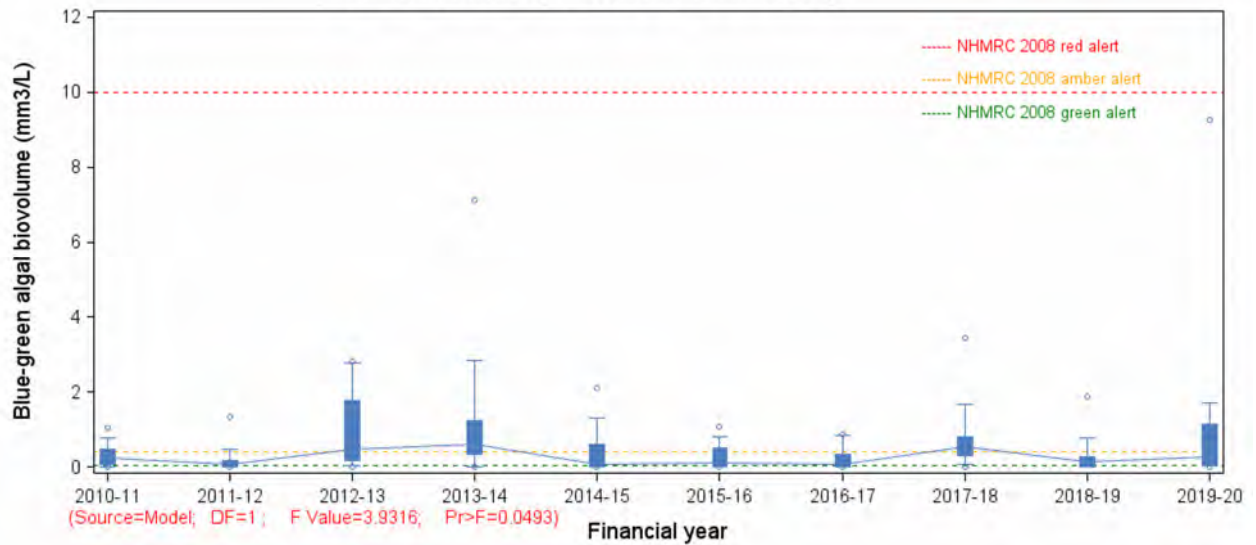
N26: Hawkesbury River at Sackville Ferry



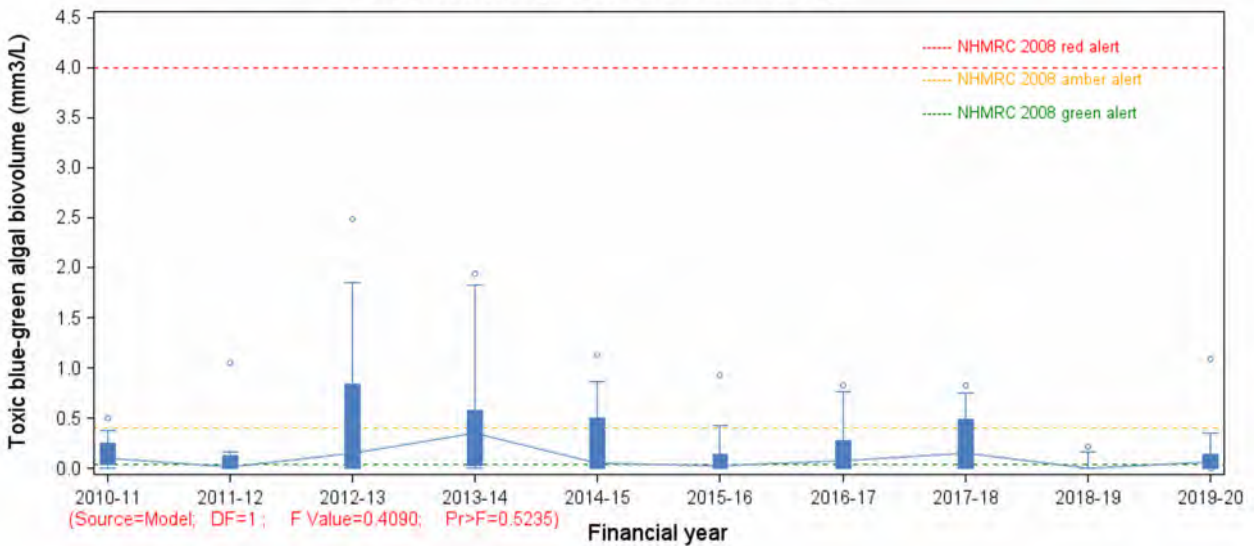
N26: Hawkesbury River at Sackville Ferry



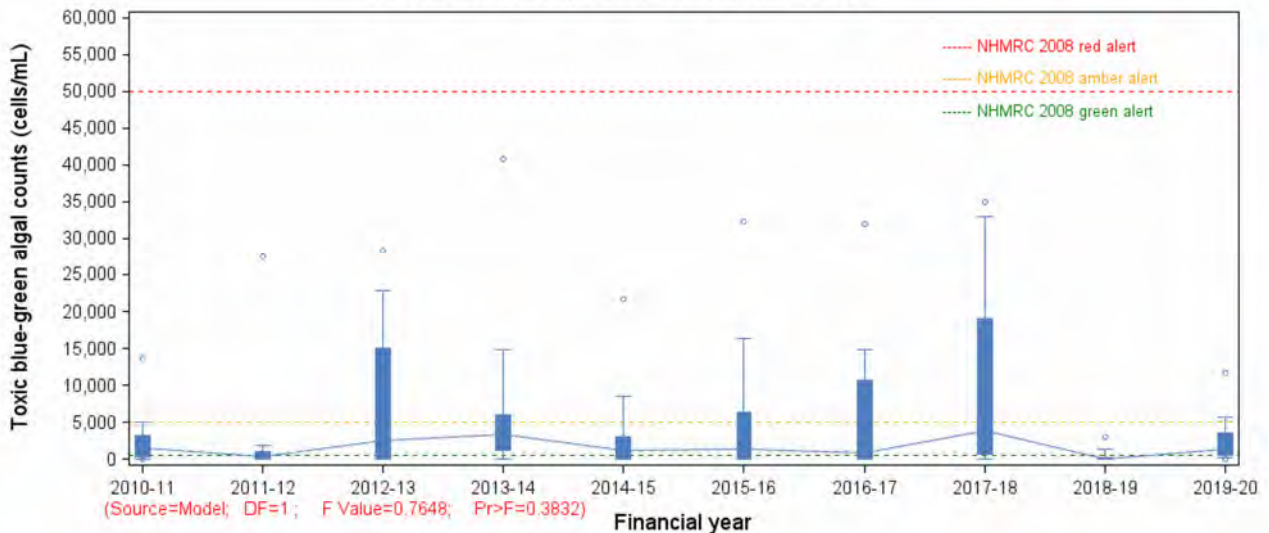
N26: Hawkesbury River at Sackville Ferry

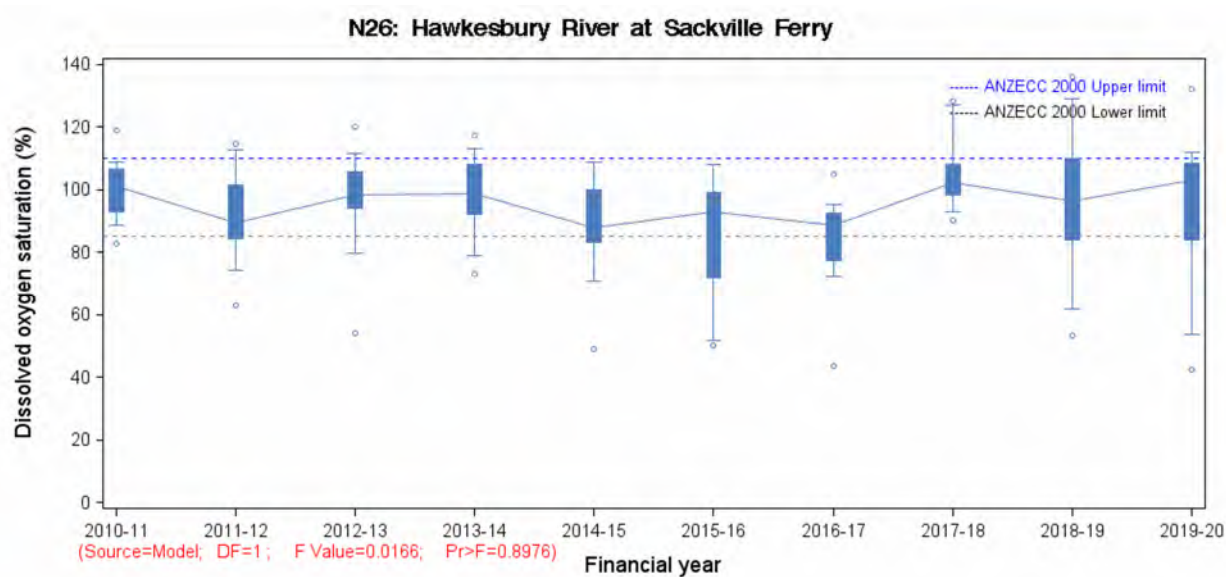
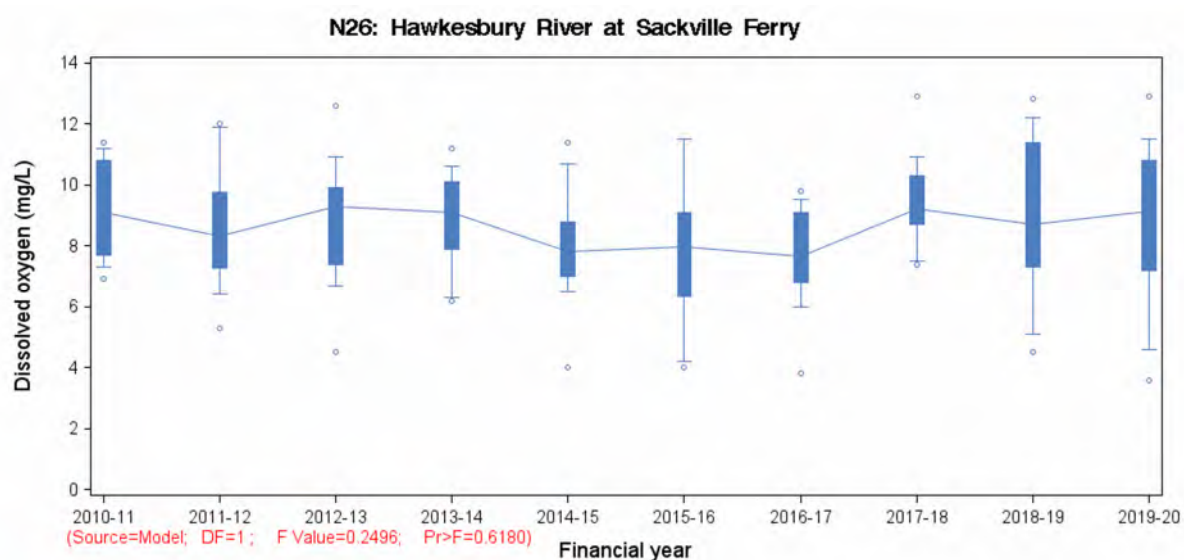
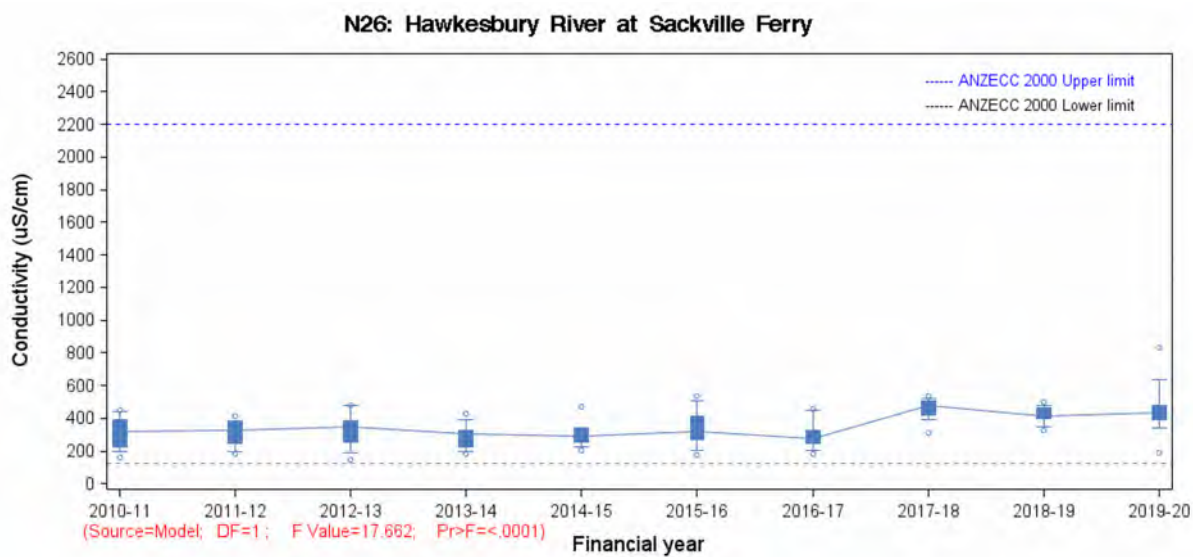


N26: Hawkesbury River at Sackville Ferry

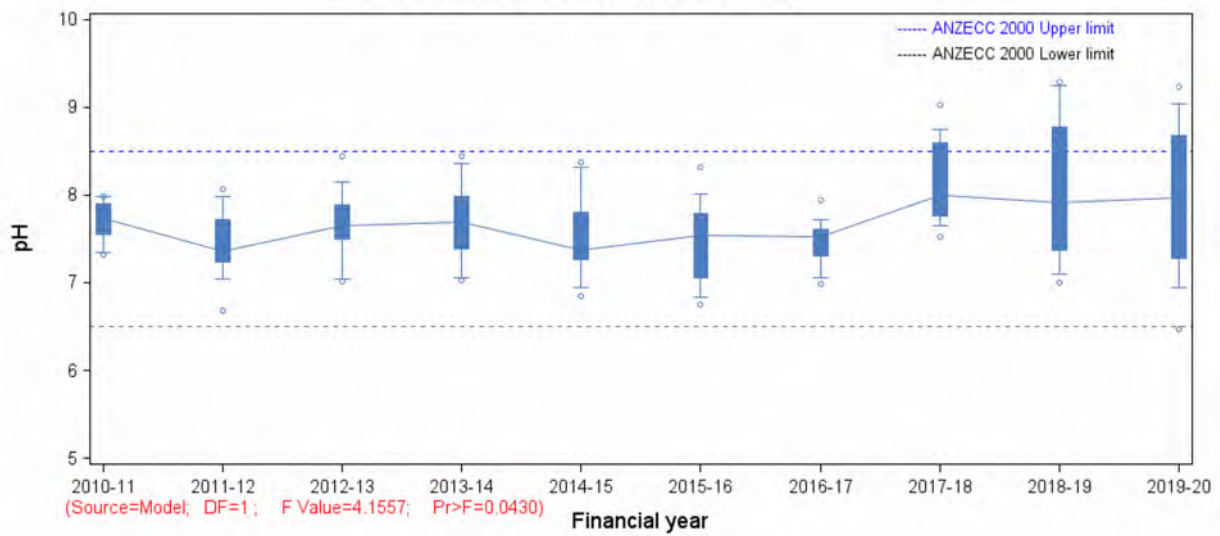


N26: Hawkesbury River at Sackville Ferry

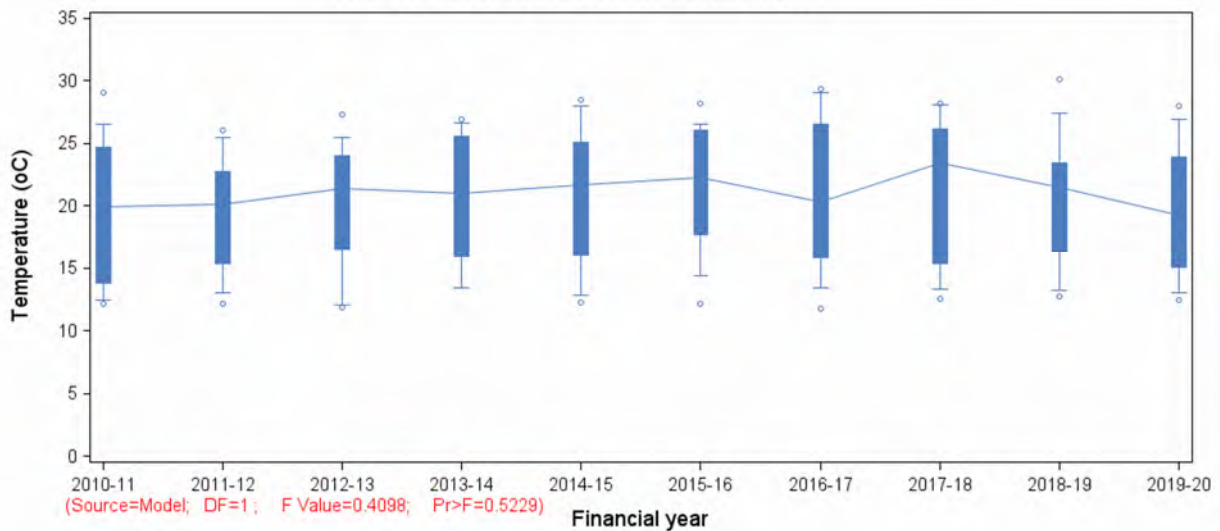




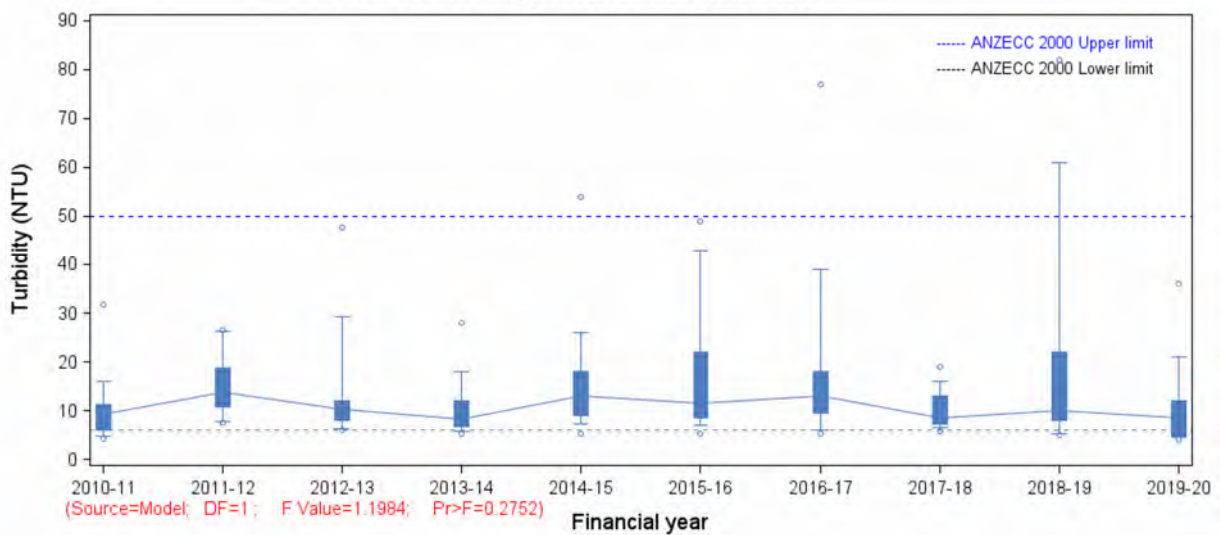
N26: Hawkesbury River Sackville Ferry



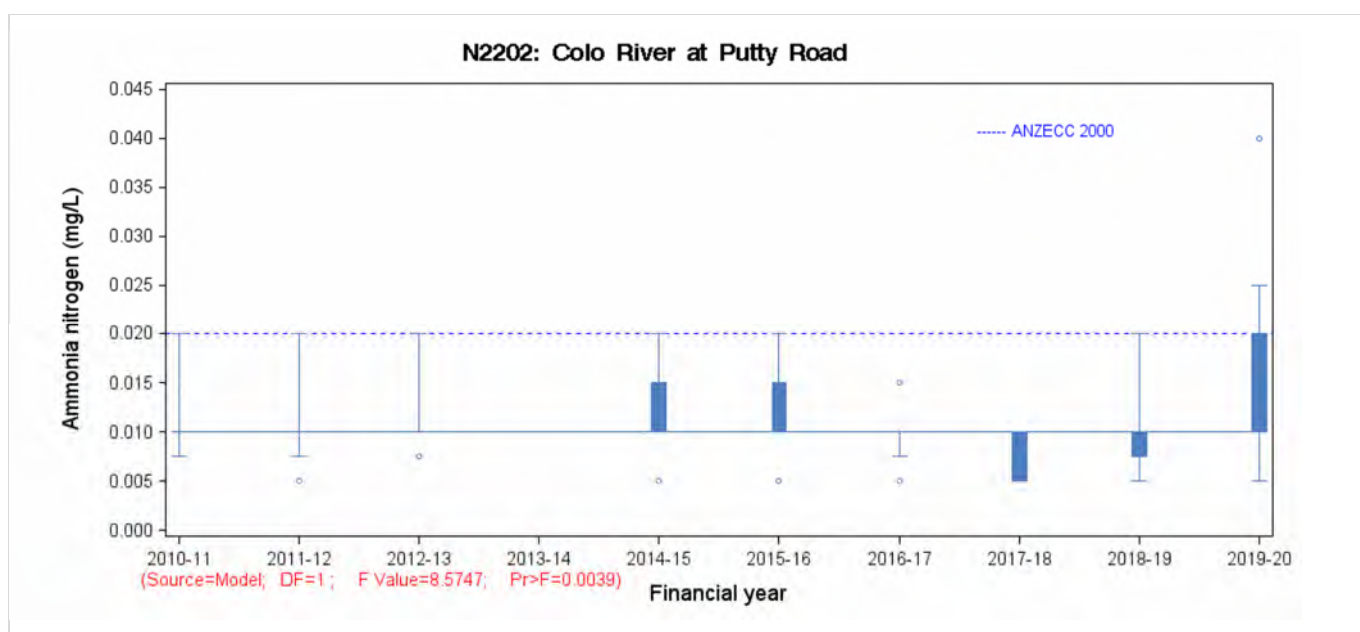
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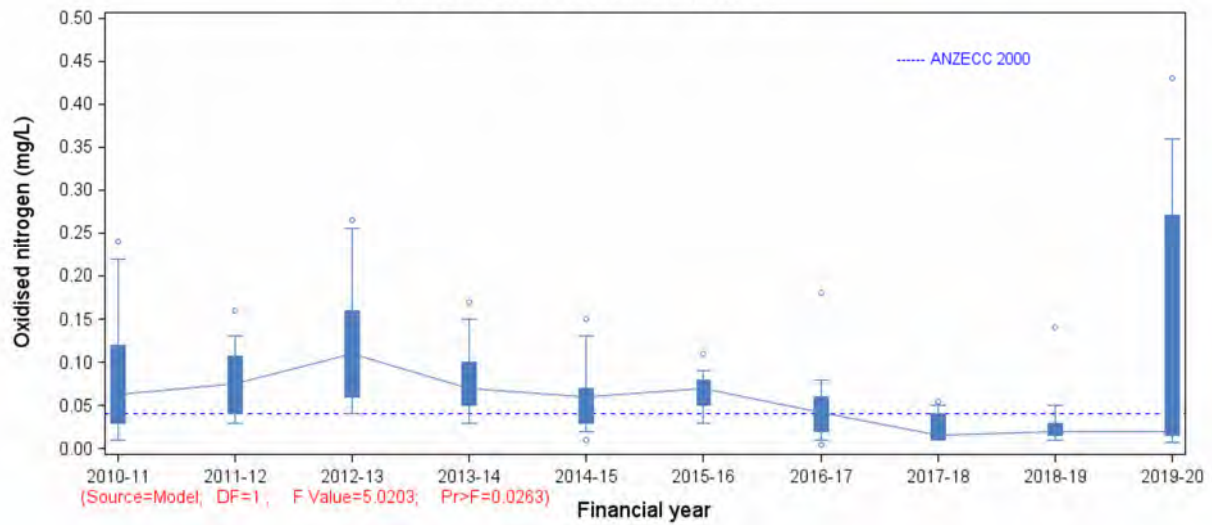
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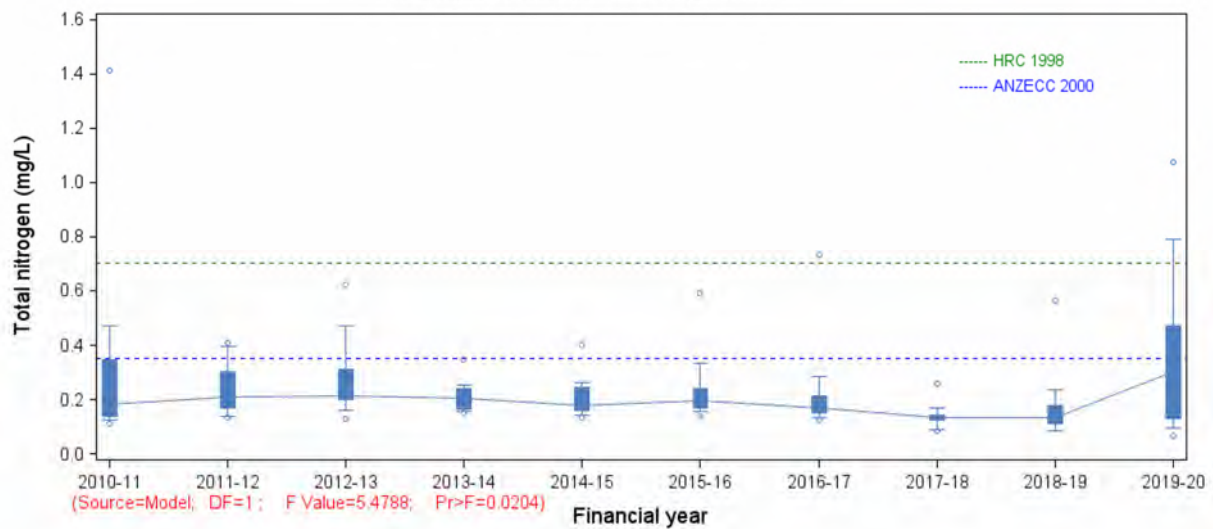
Nutrients, chlorophyll-a and algae



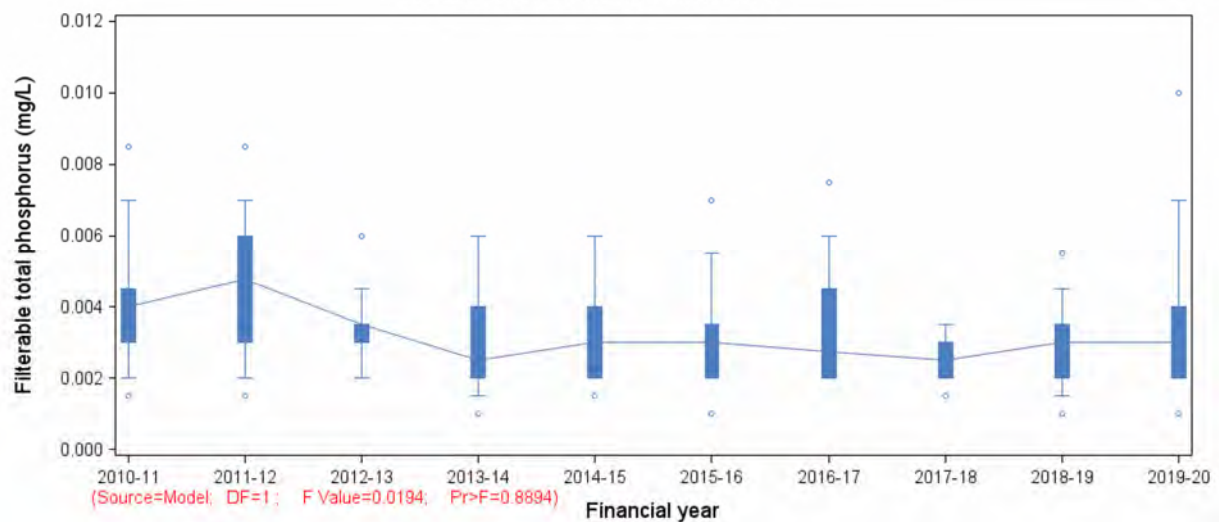
N2202: Colo River at Putty Road



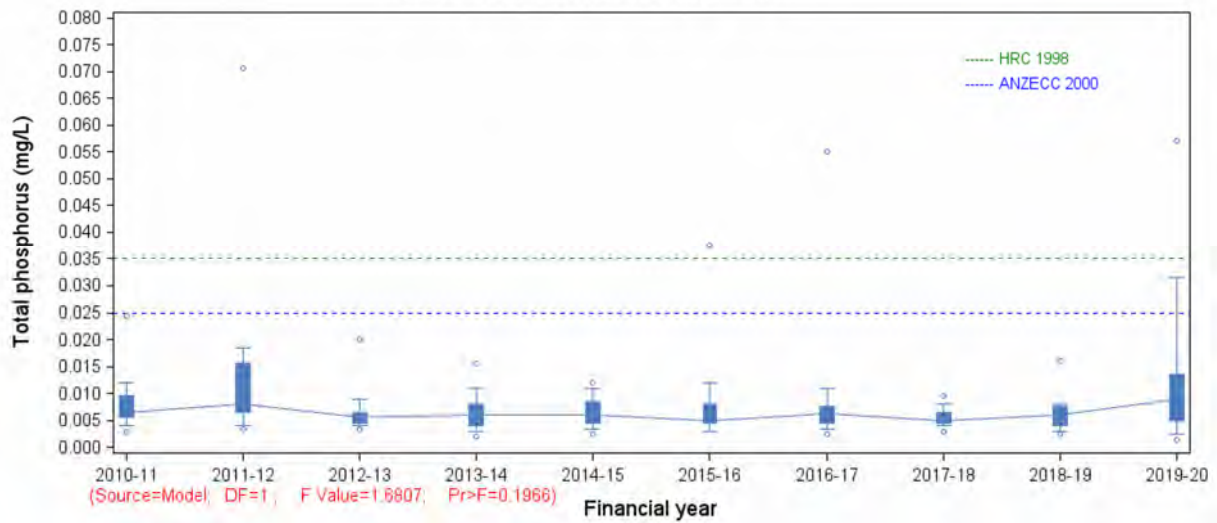
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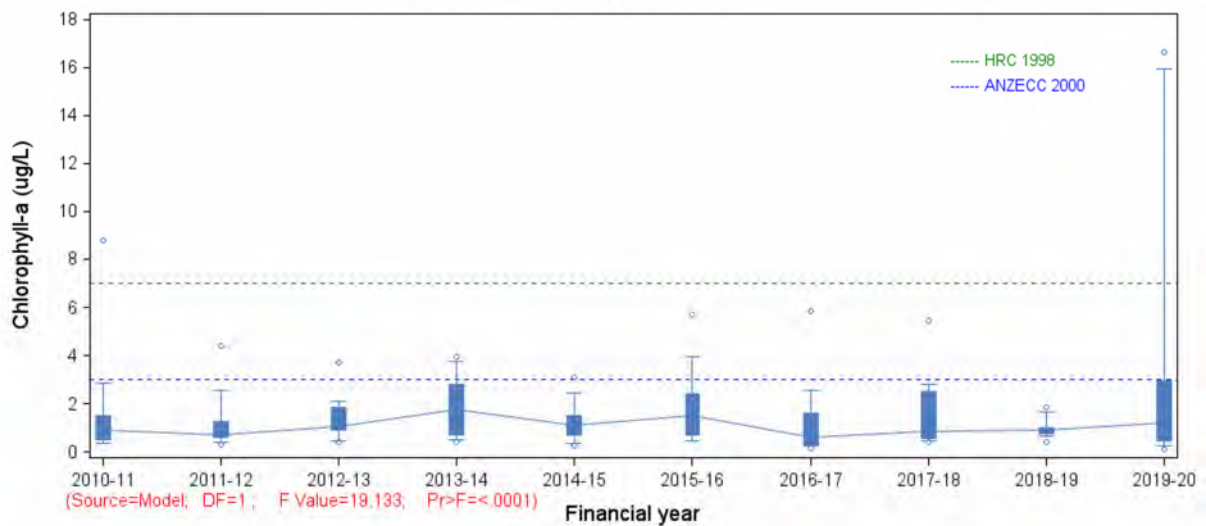
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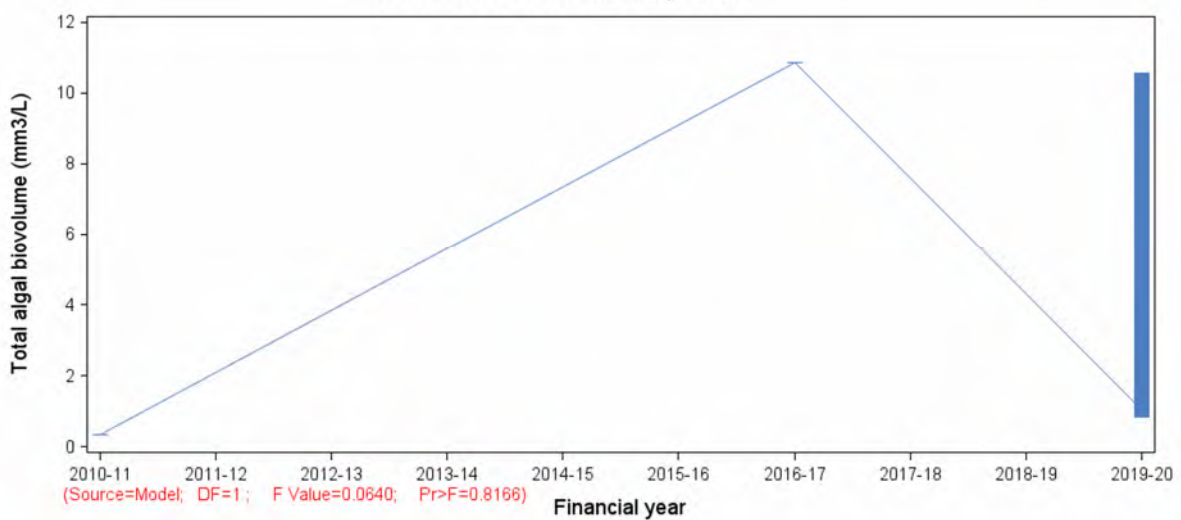
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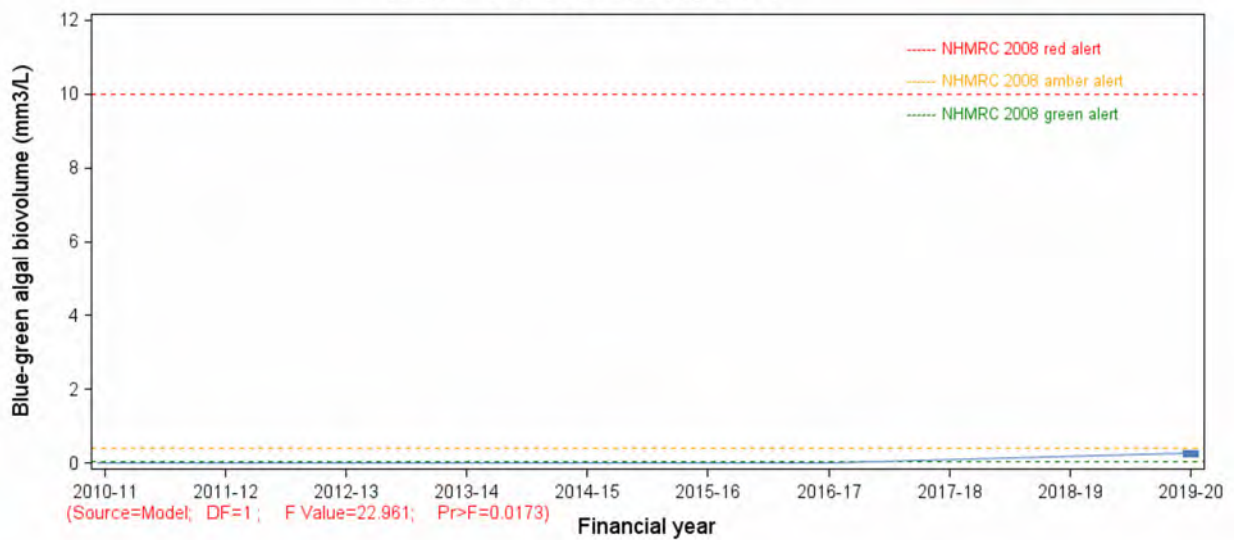
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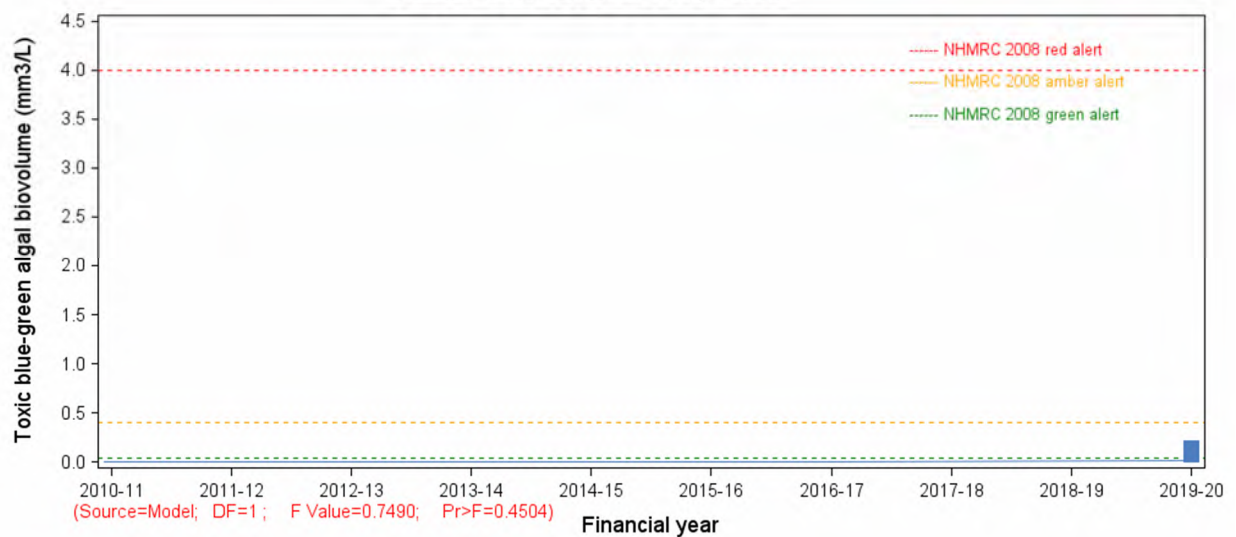
N2202: Colo River at Putty Road



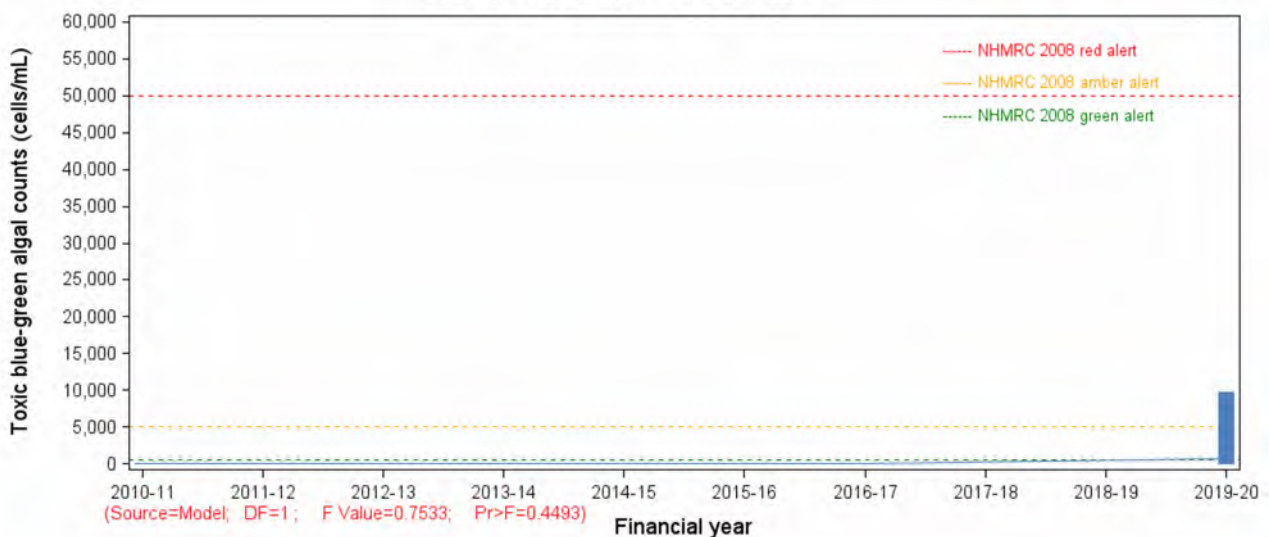
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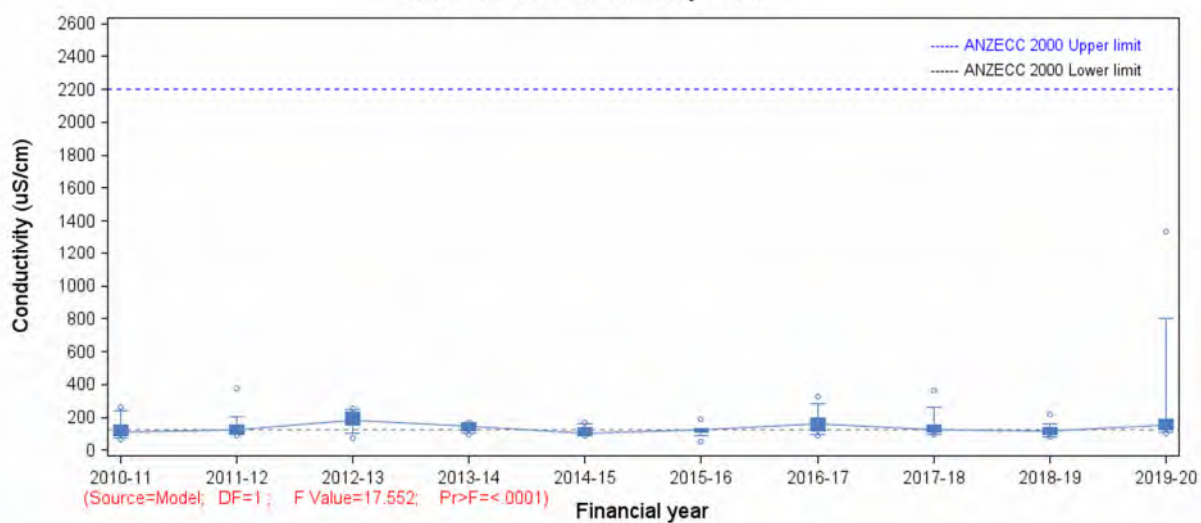
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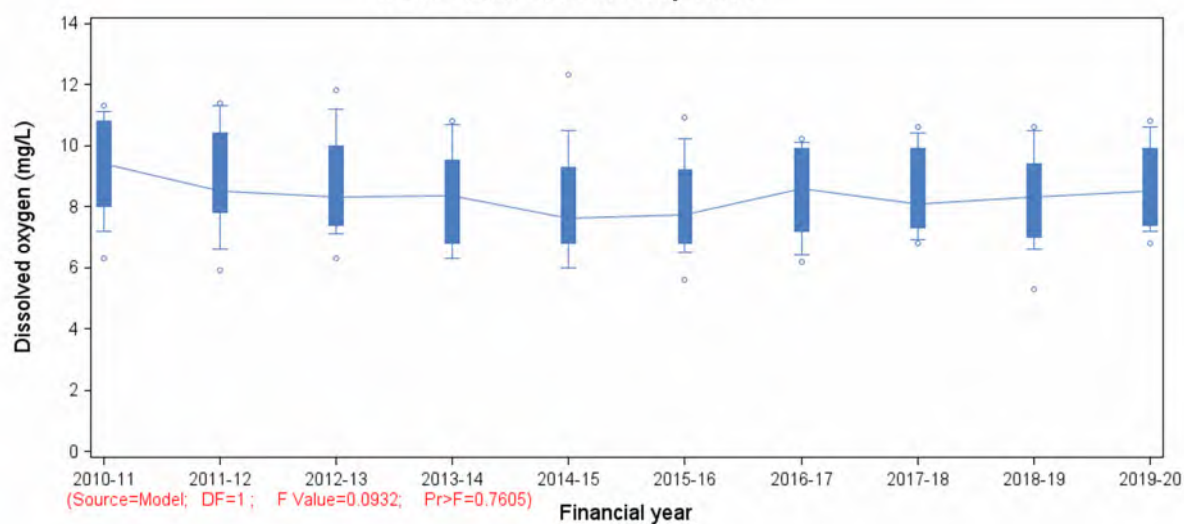
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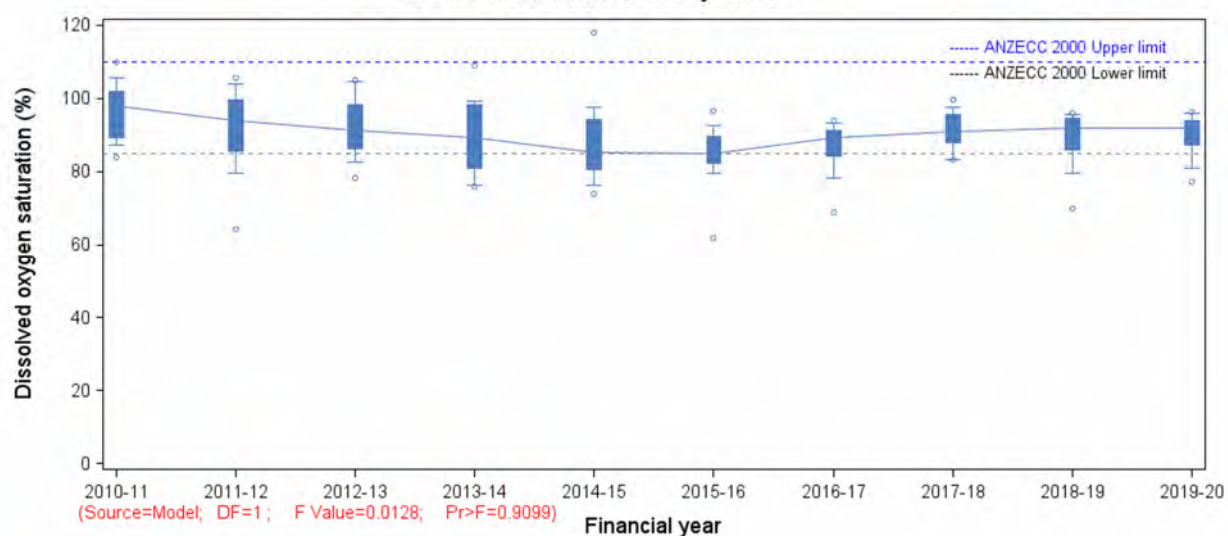
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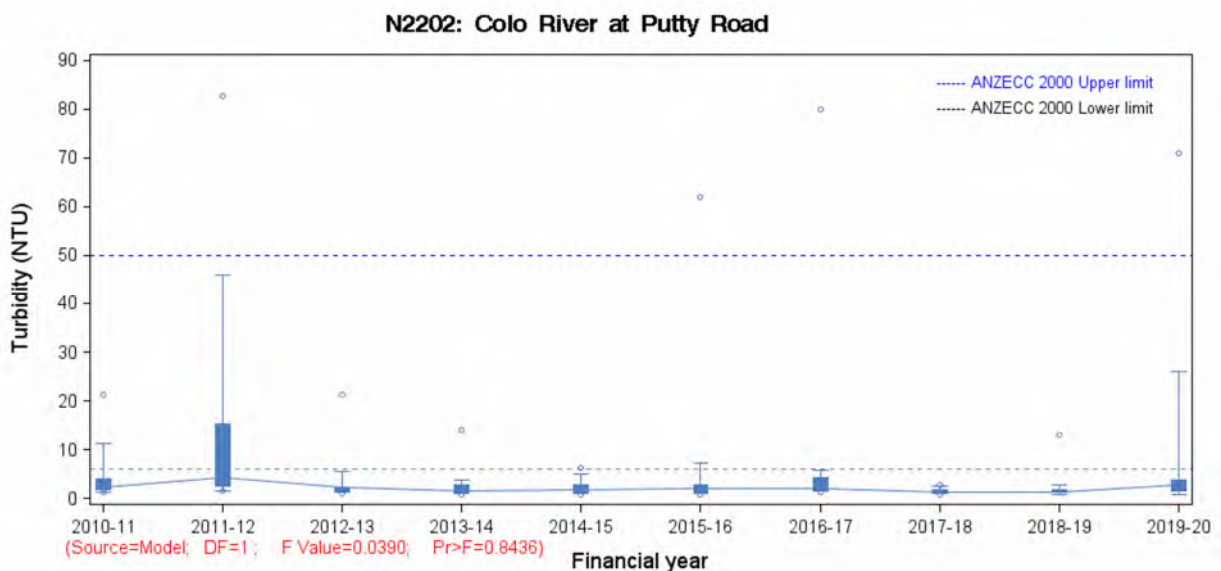
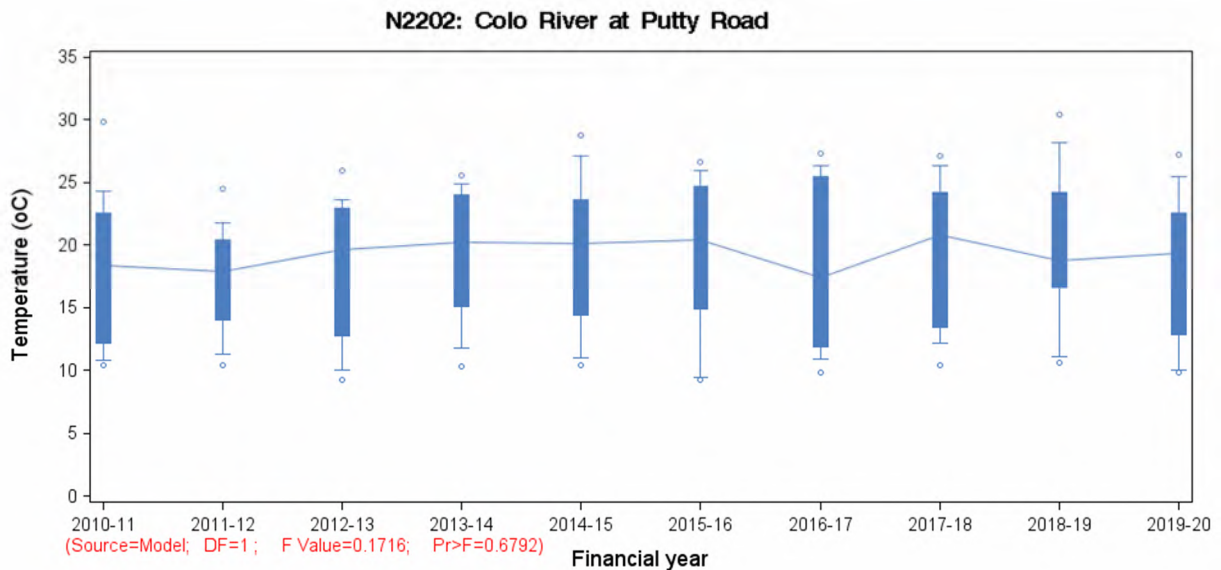
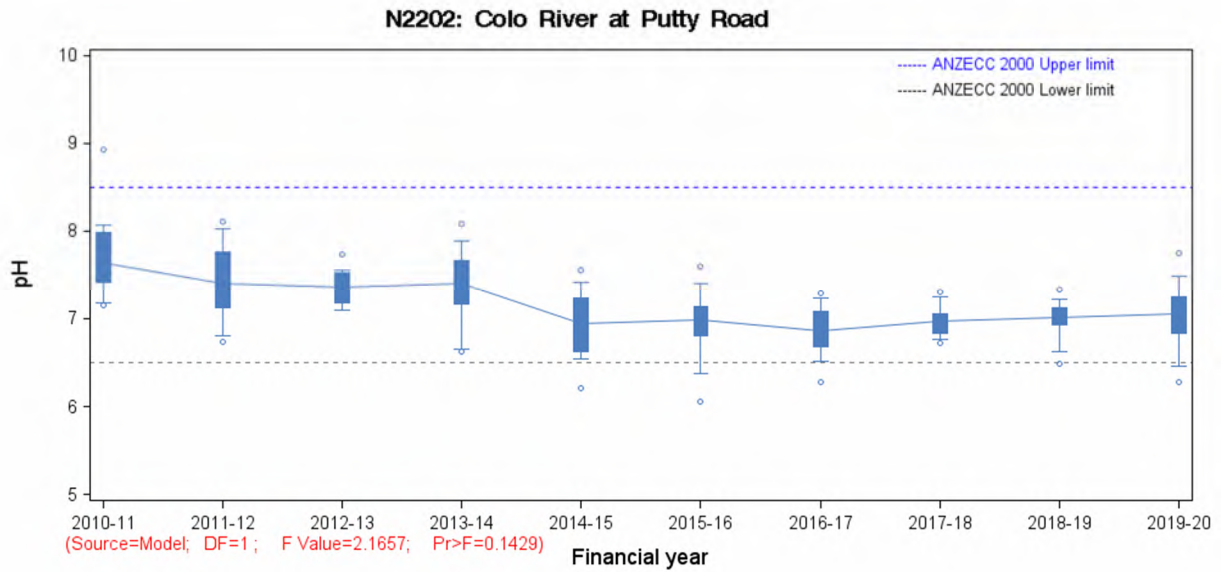


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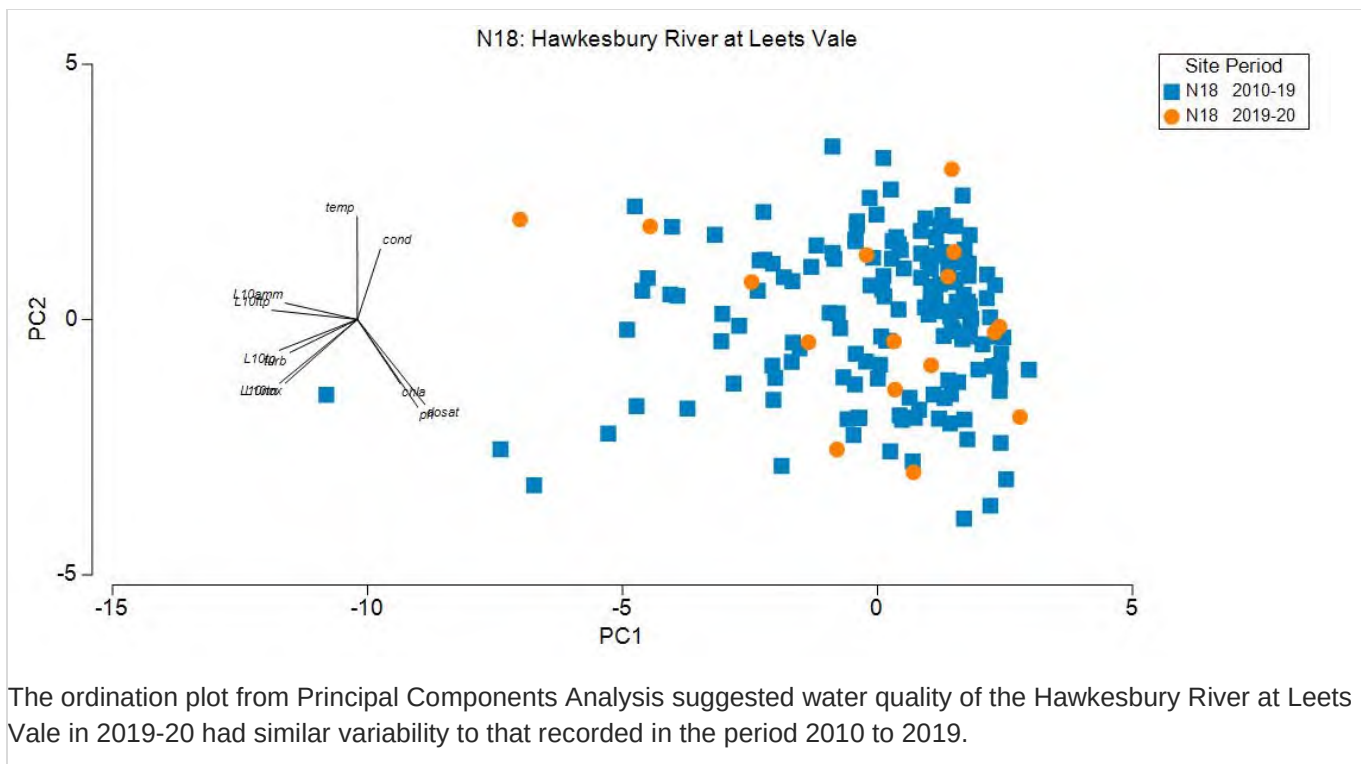


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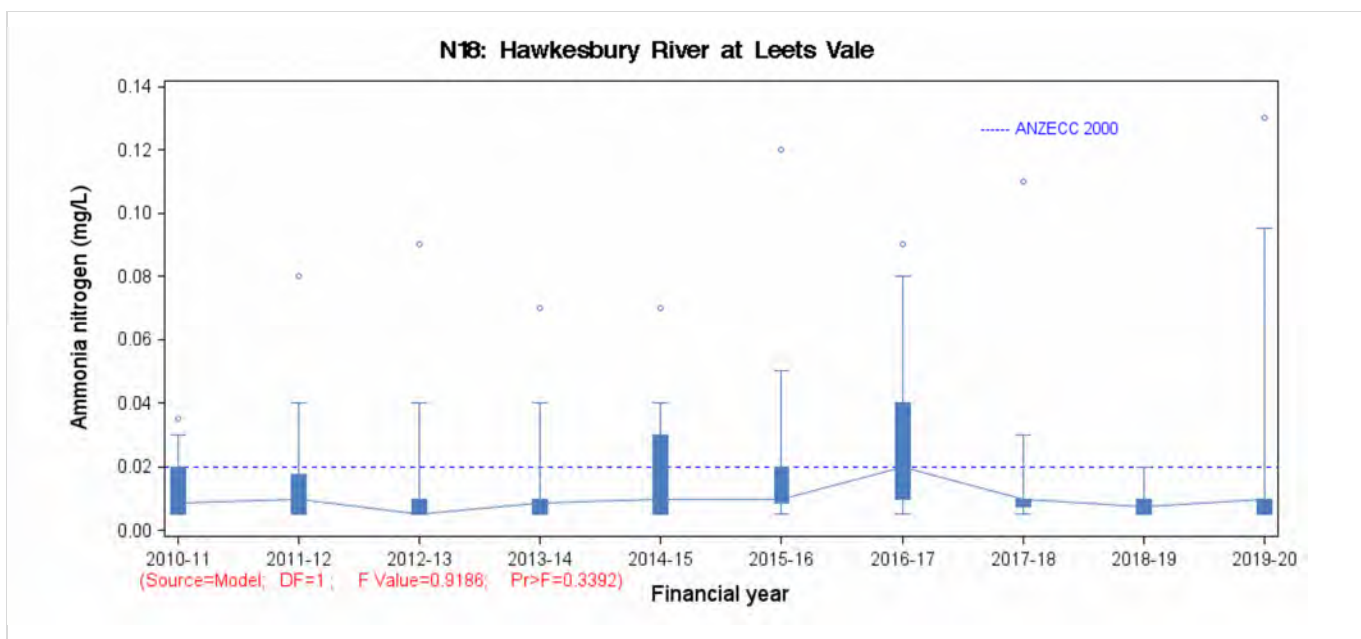




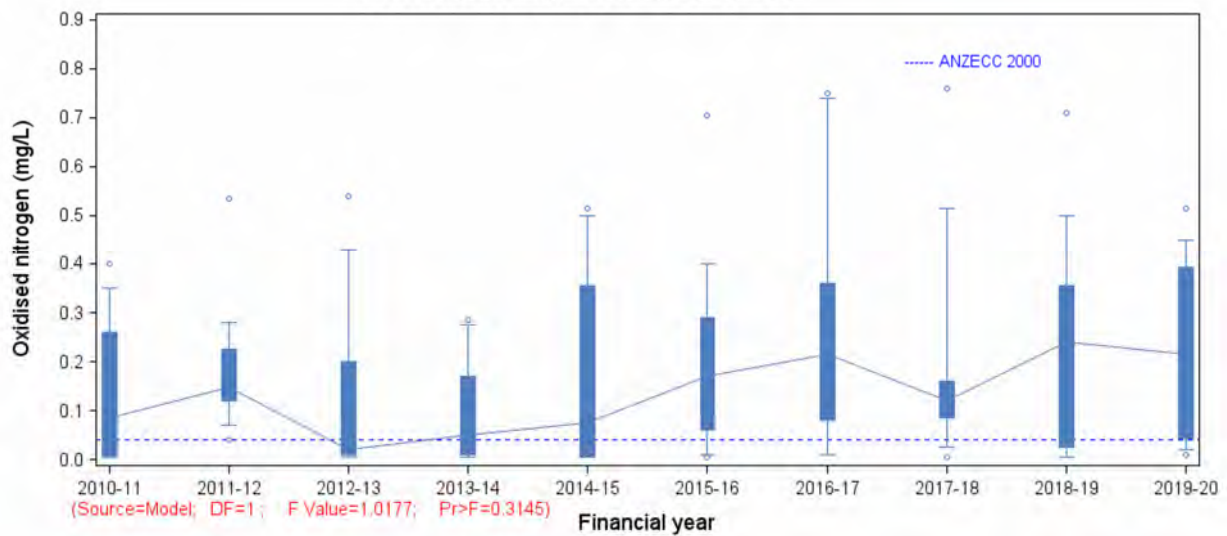
N18: Hawkesbury River at Leets Vale



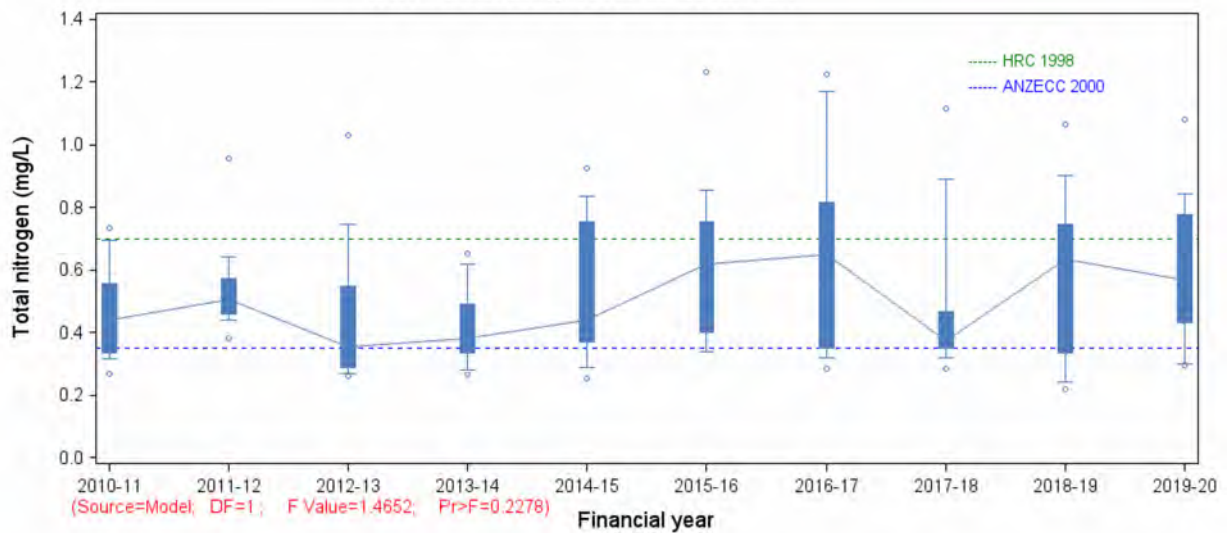
Nutrients, chlorophyll-a and algae



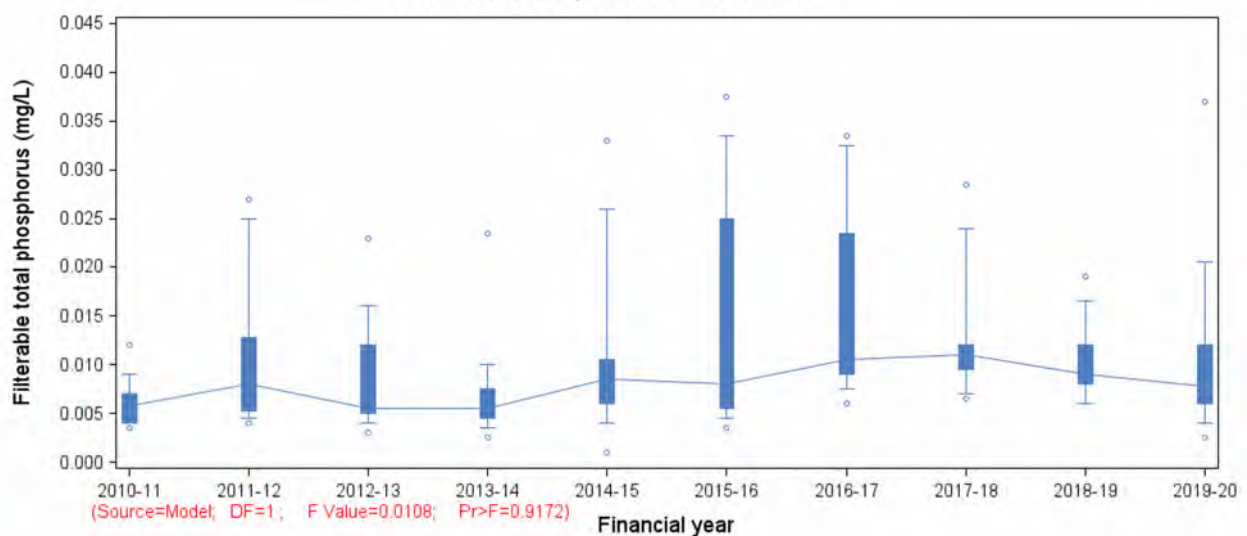
N18: Hawkesbury River at Leets Vale



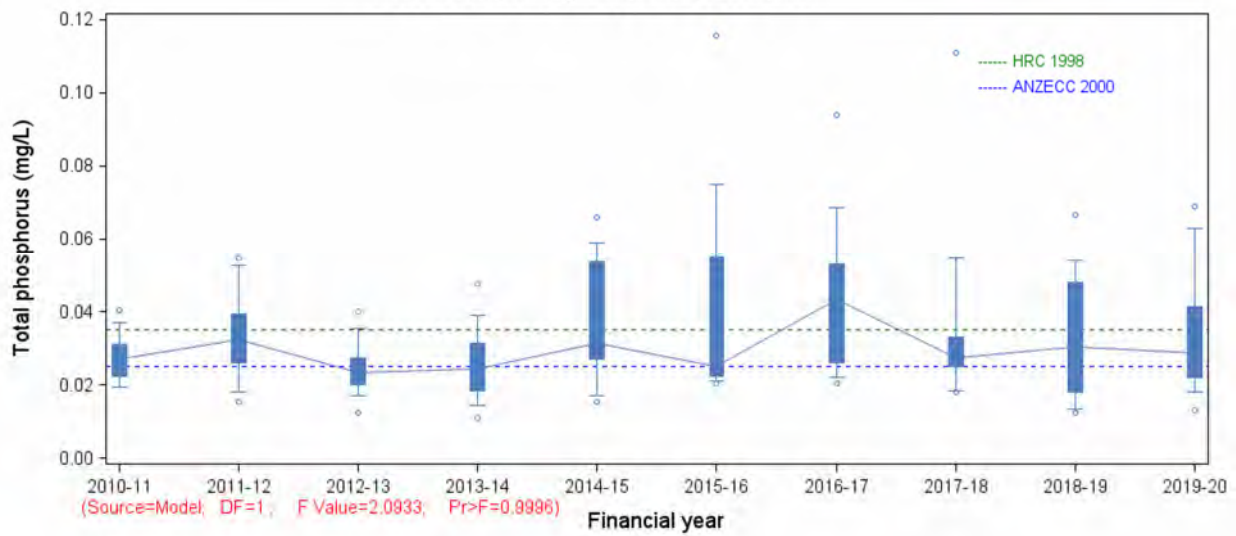
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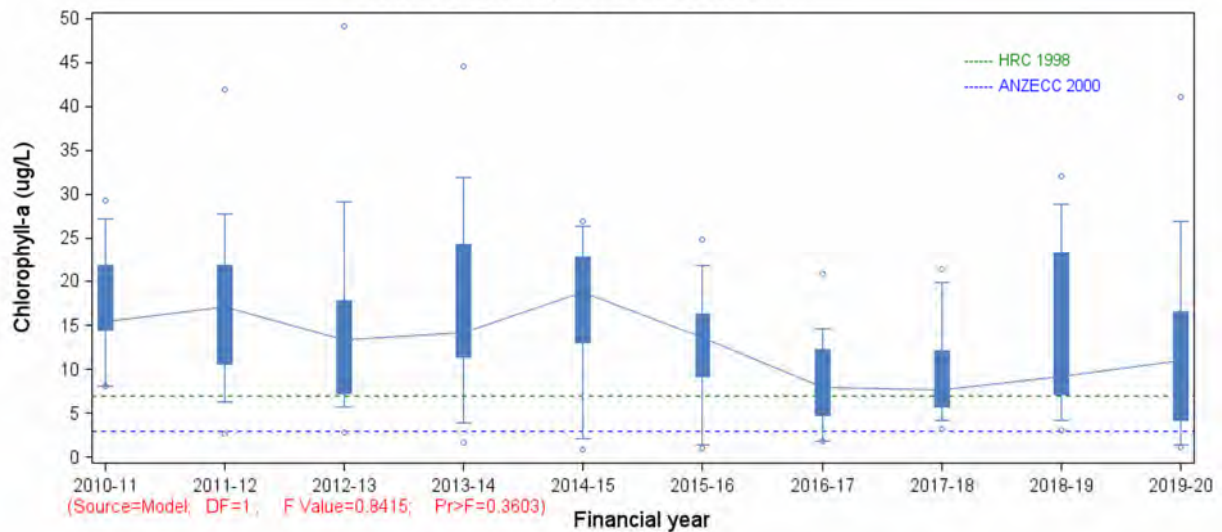
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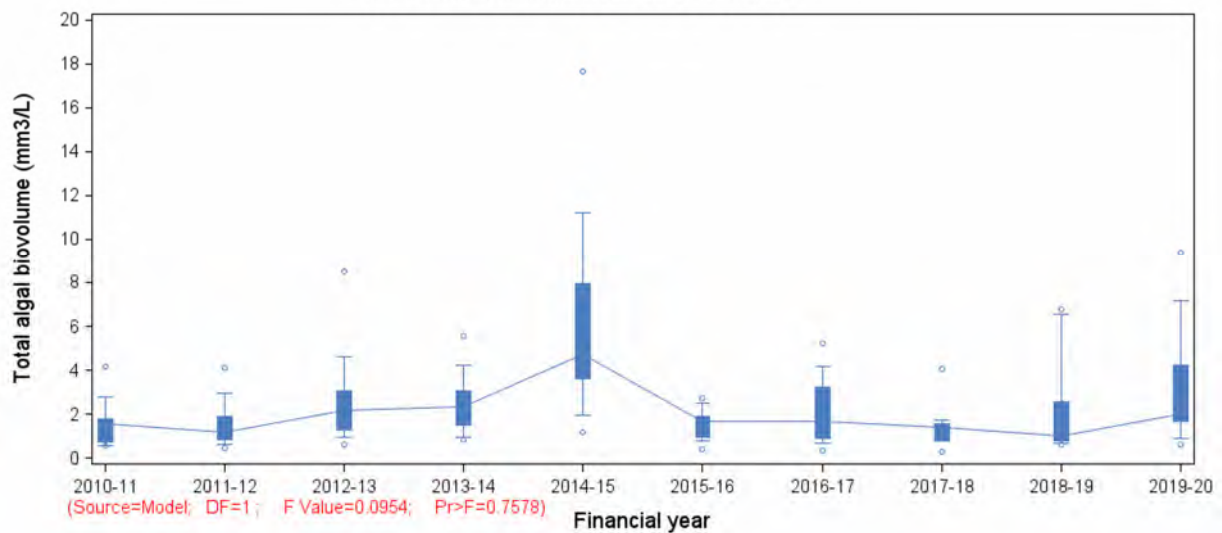
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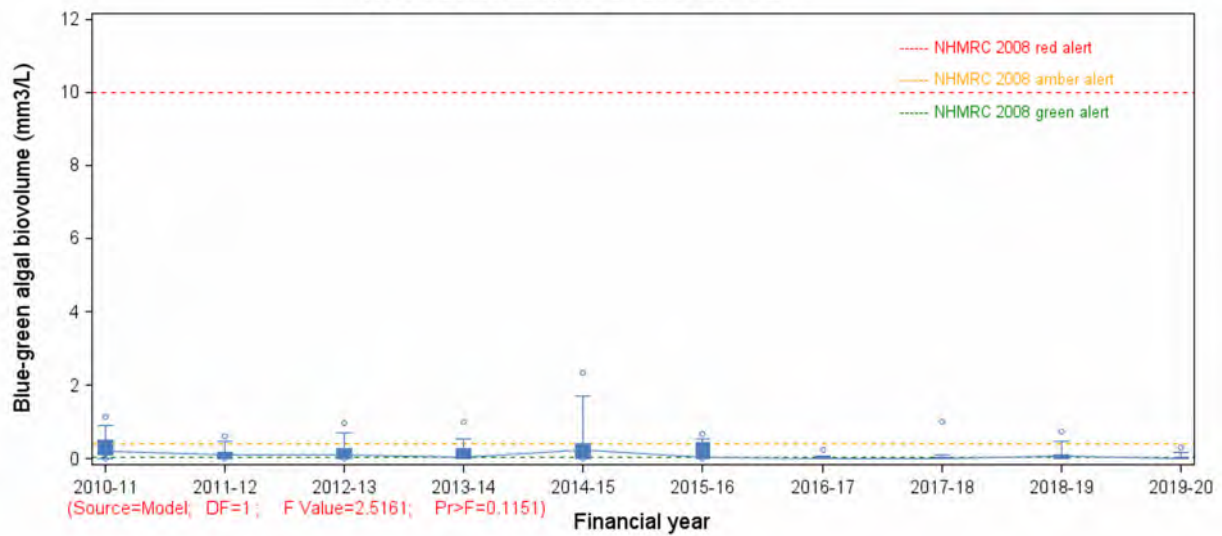
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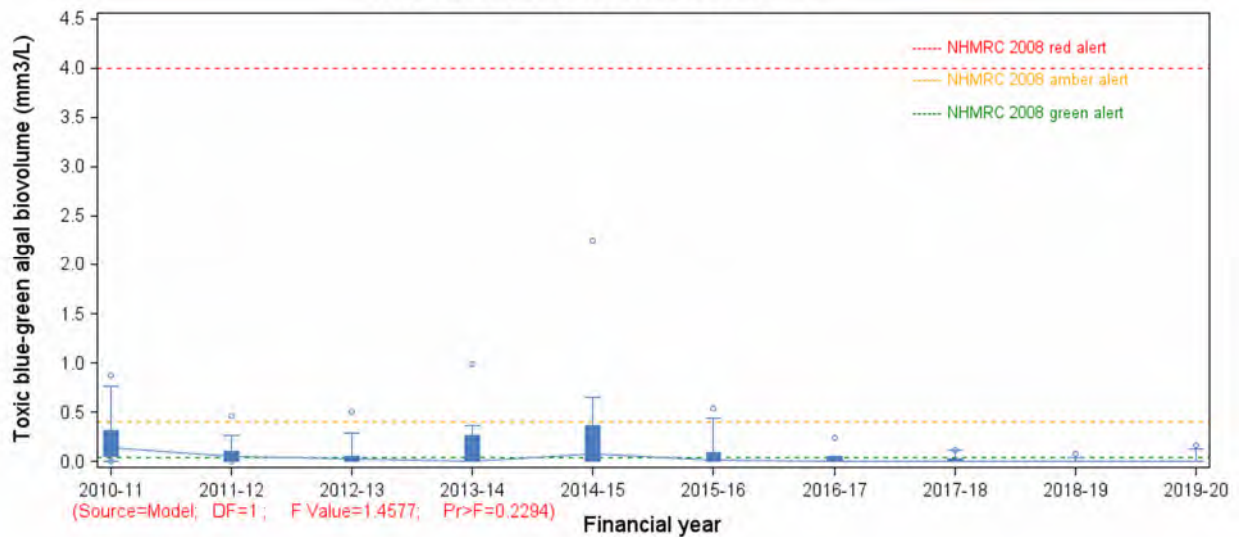
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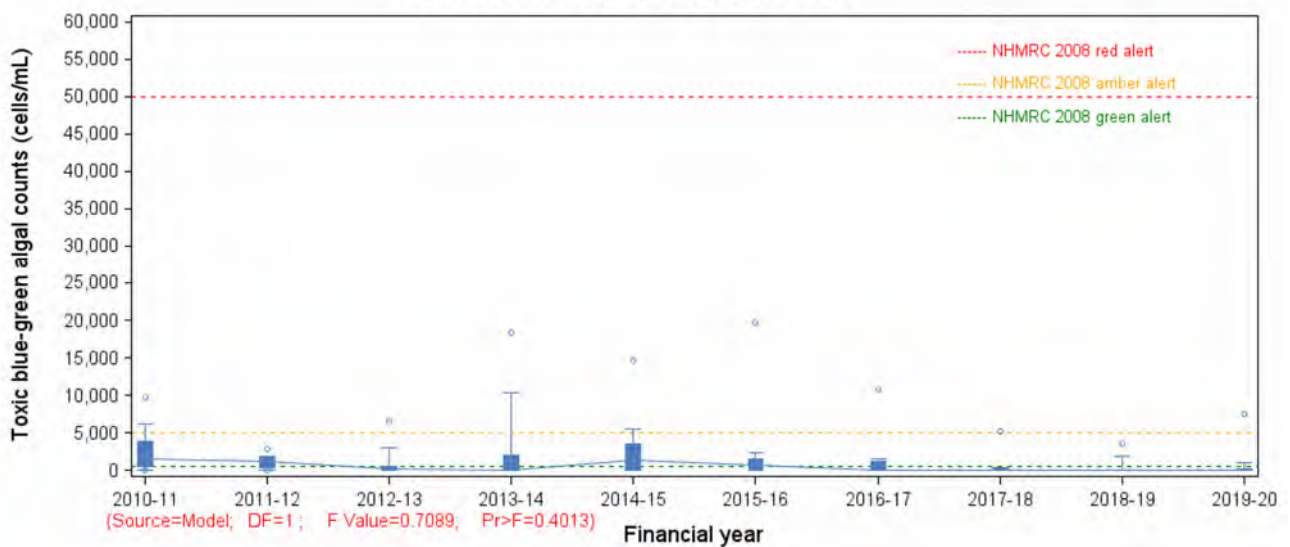
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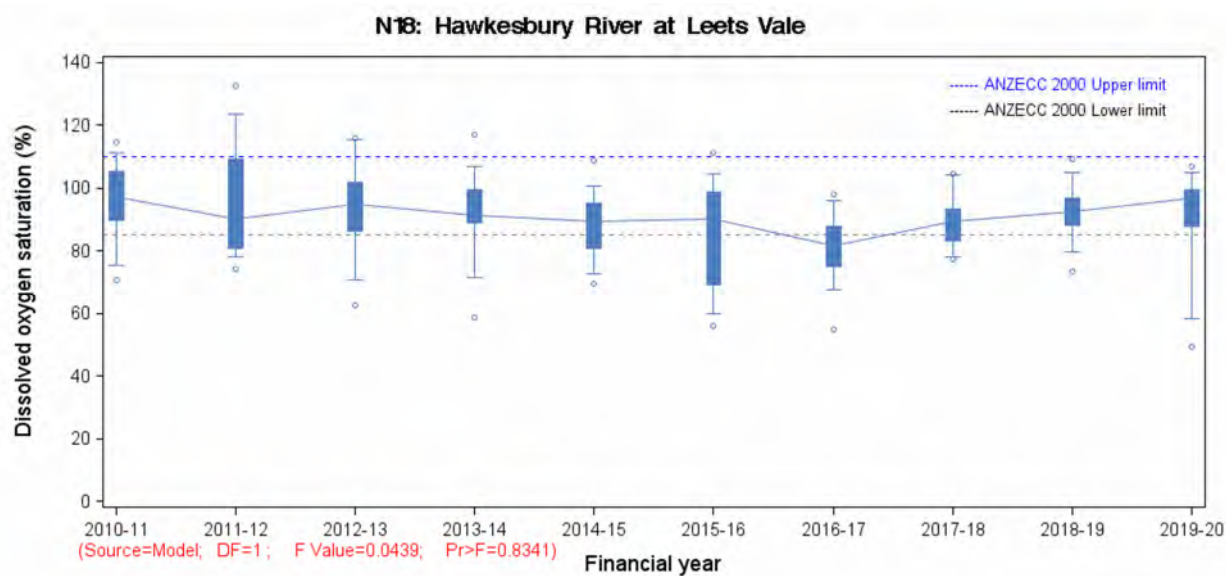
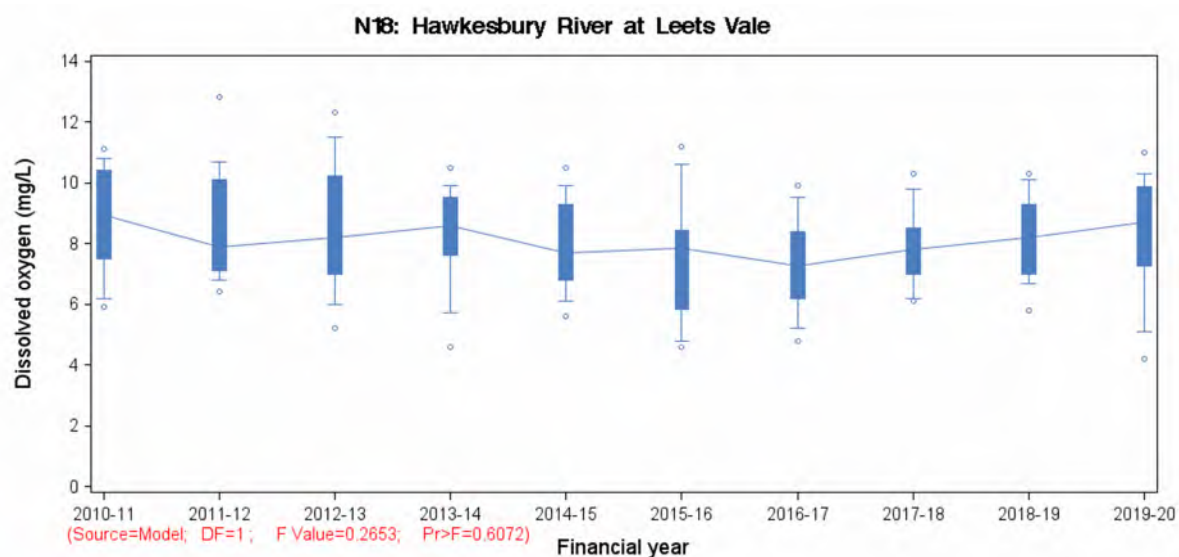
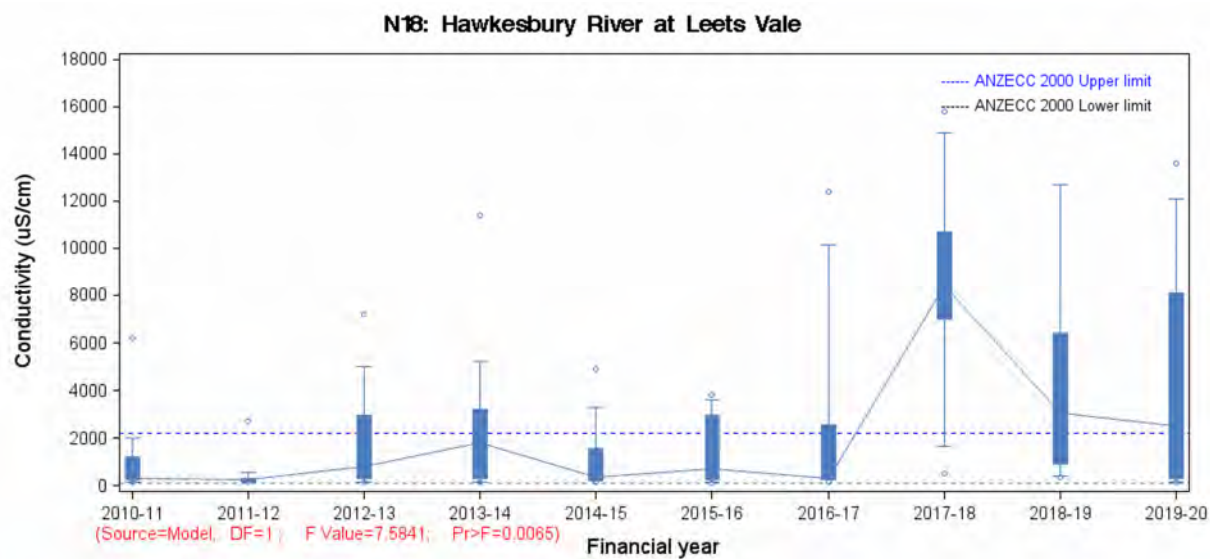


N18: Hawkesbury River at Leets Vale

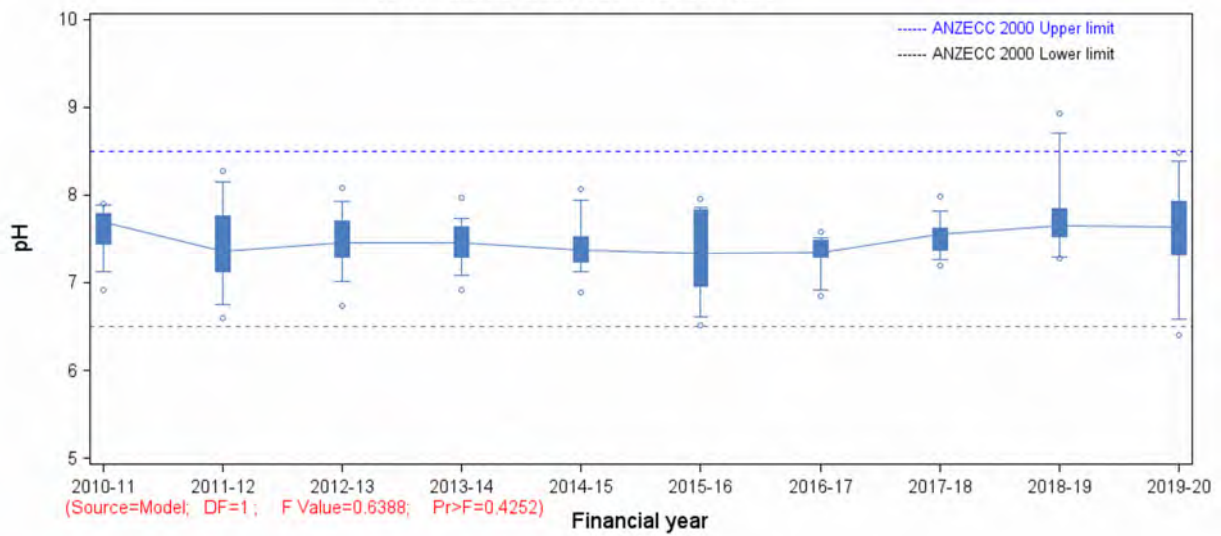


N18: Hawkesbury River at Leets Vale

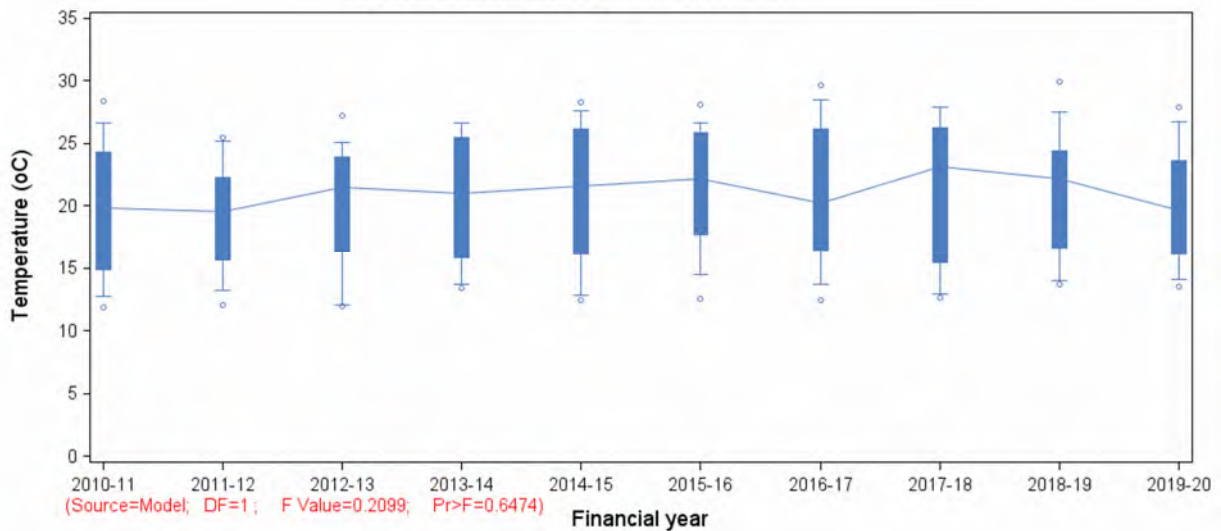




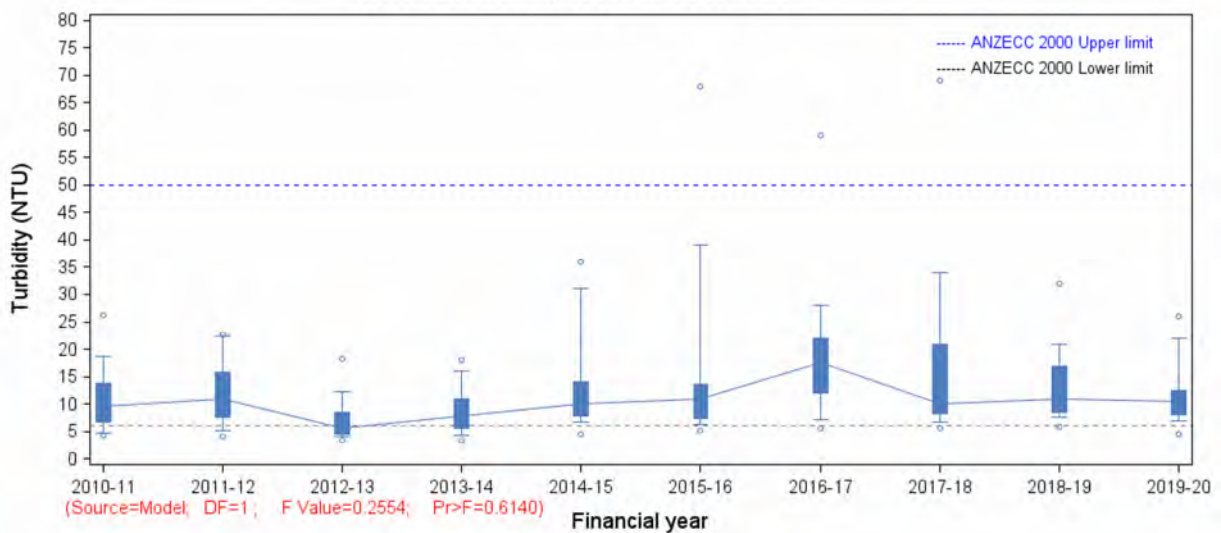
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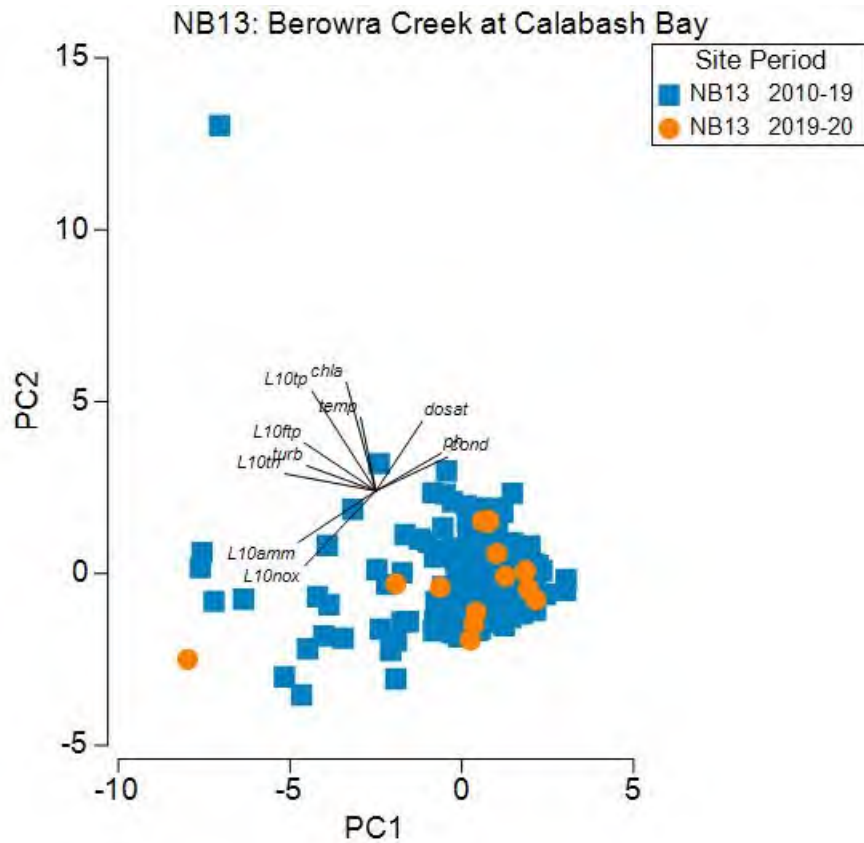
N18: Hawkesbury River at Leets Vale



N18: Hawkesbury River at Leets Vale

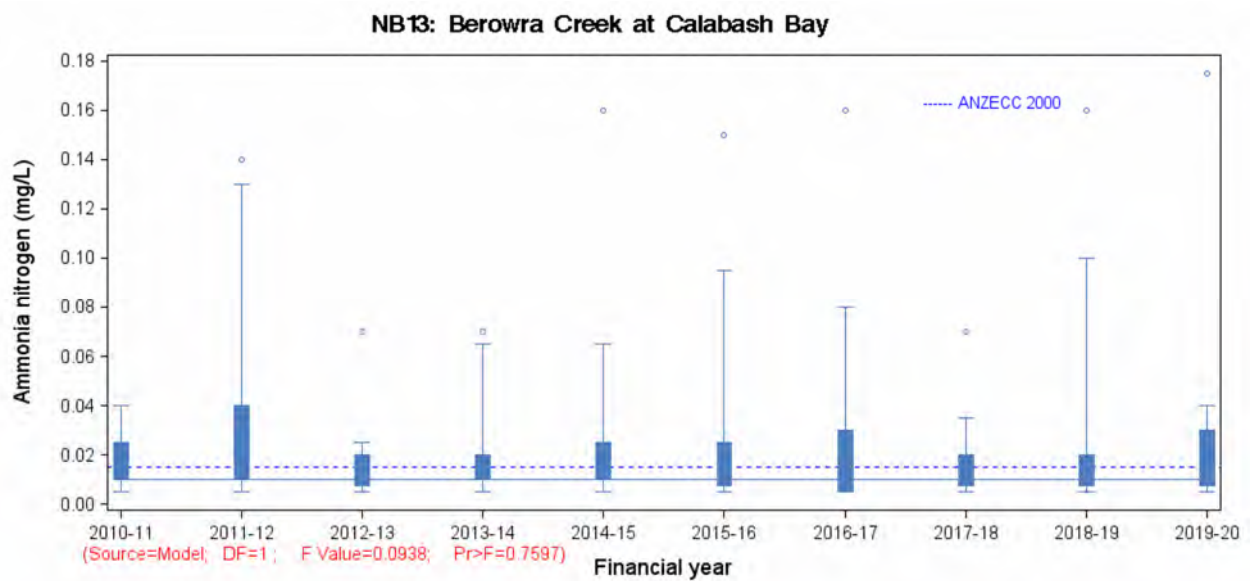


NB13: Berowra Creek at Calabash Bay

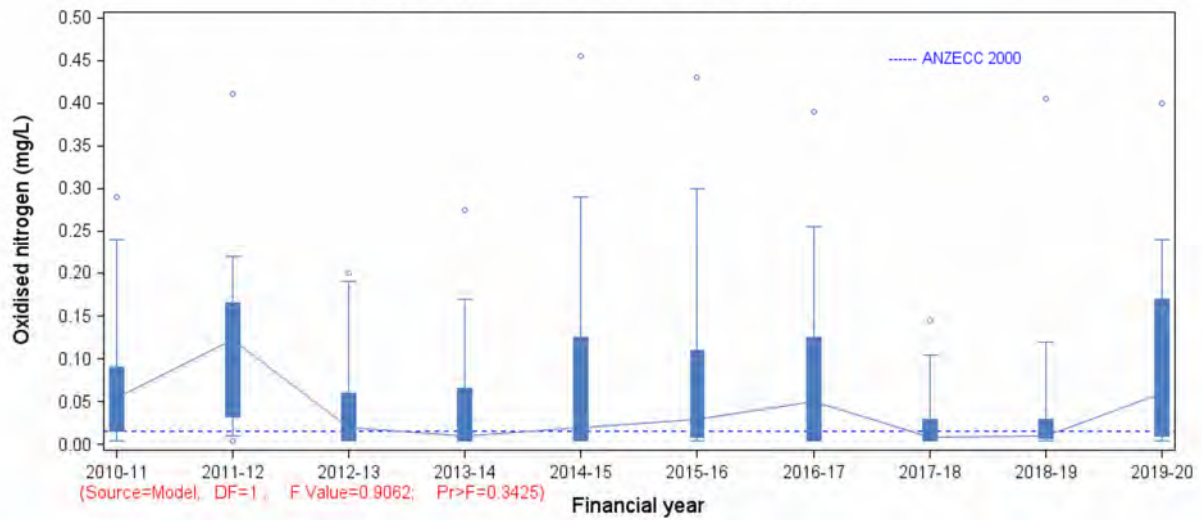


The ordination plot from Principal Components Analysis suggested water quality of Berowra Creek at Calabash Bay in 2019-20 was similar to that recorded in the period 2010 to 2019.

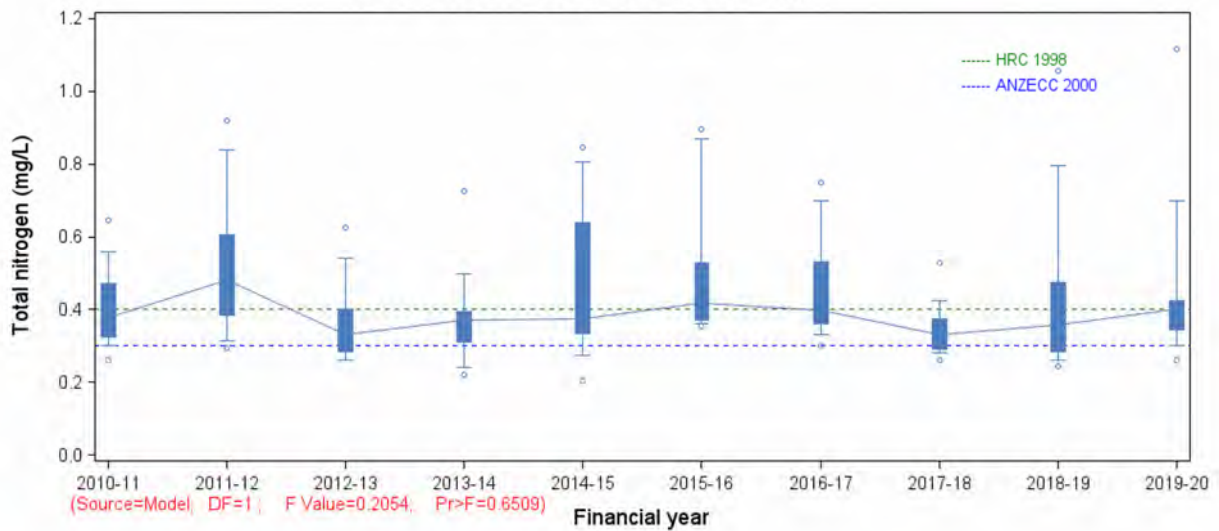
Nutrients, chlorophyll-a and algae



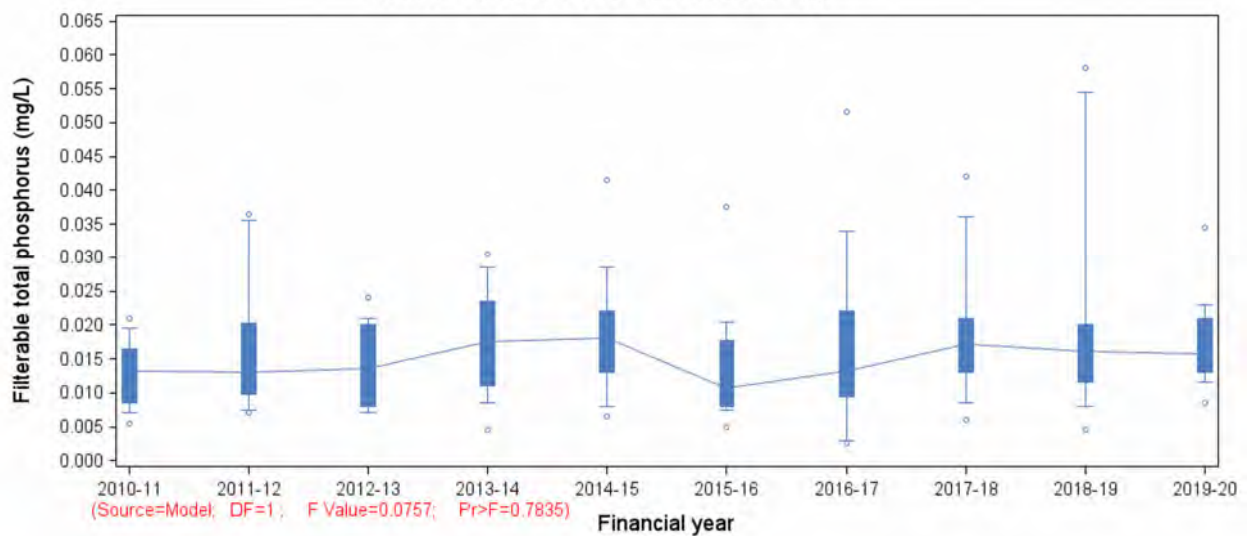
NB13: Berowra Creek at Calabash Bay



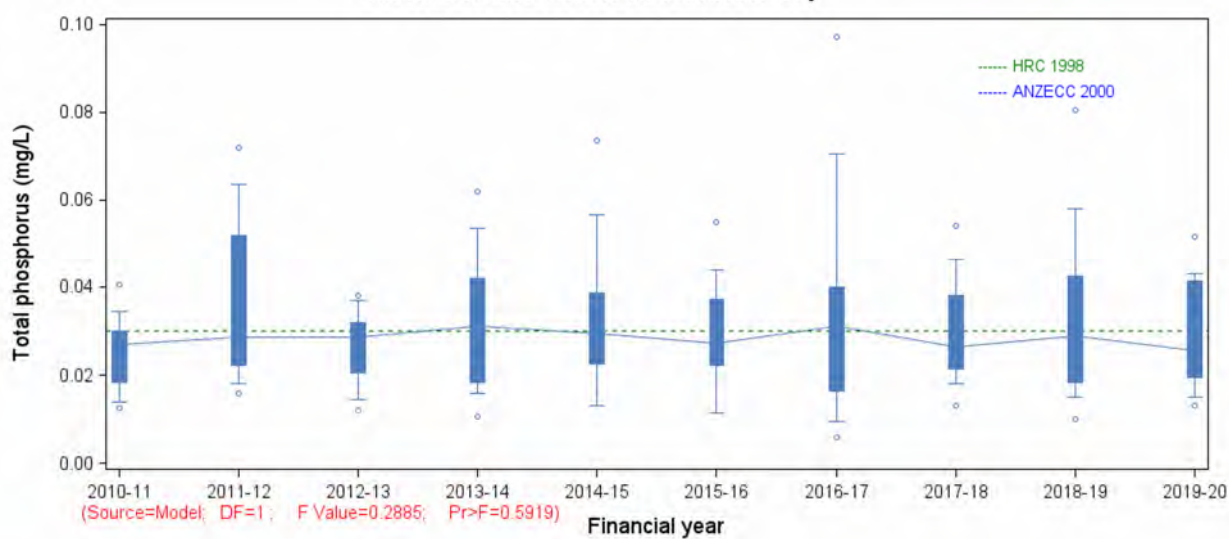
NB13: Berowra Creek at Calabash Bay



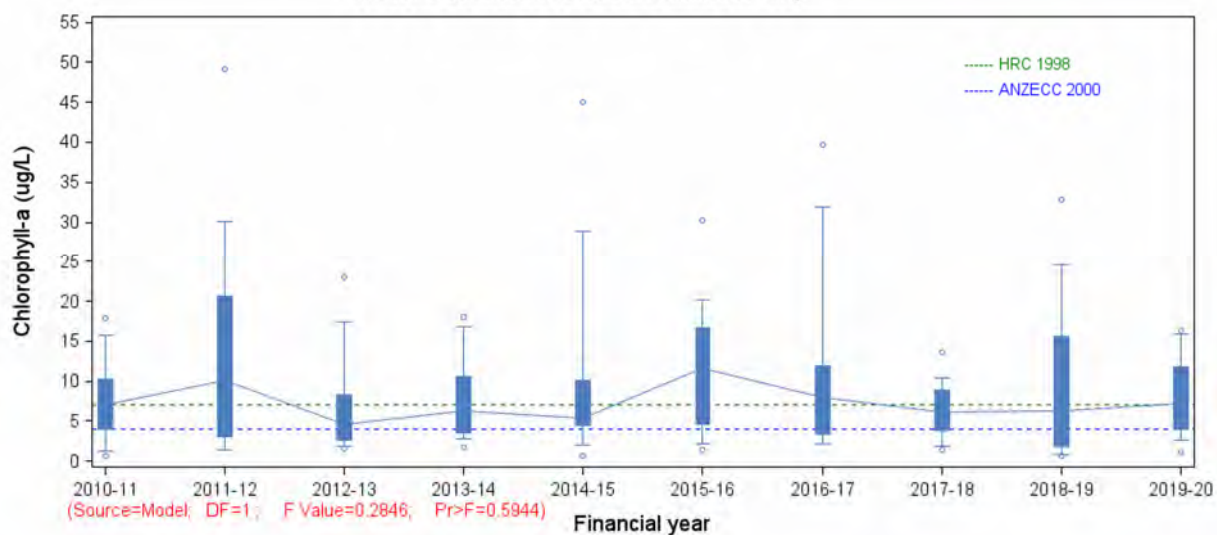
NB13: Berowra Creek at Calabash Bay



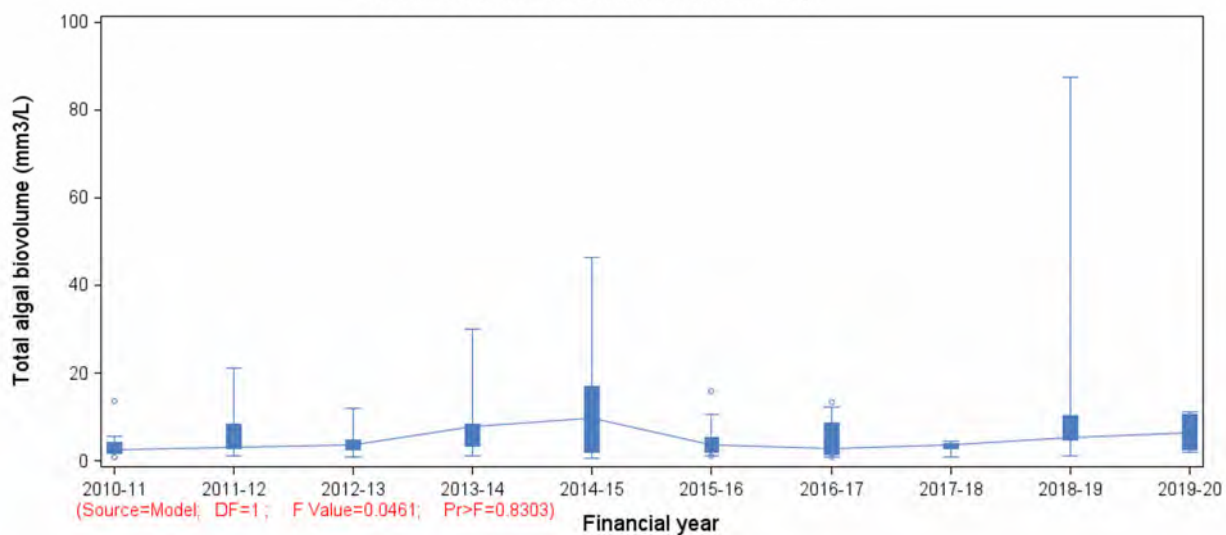
NB13: Berowra Creek at Calabash Bay



NB13: Berowra Creek at Calabash Bay



NB13: Berowra Creek at Calabash Bay

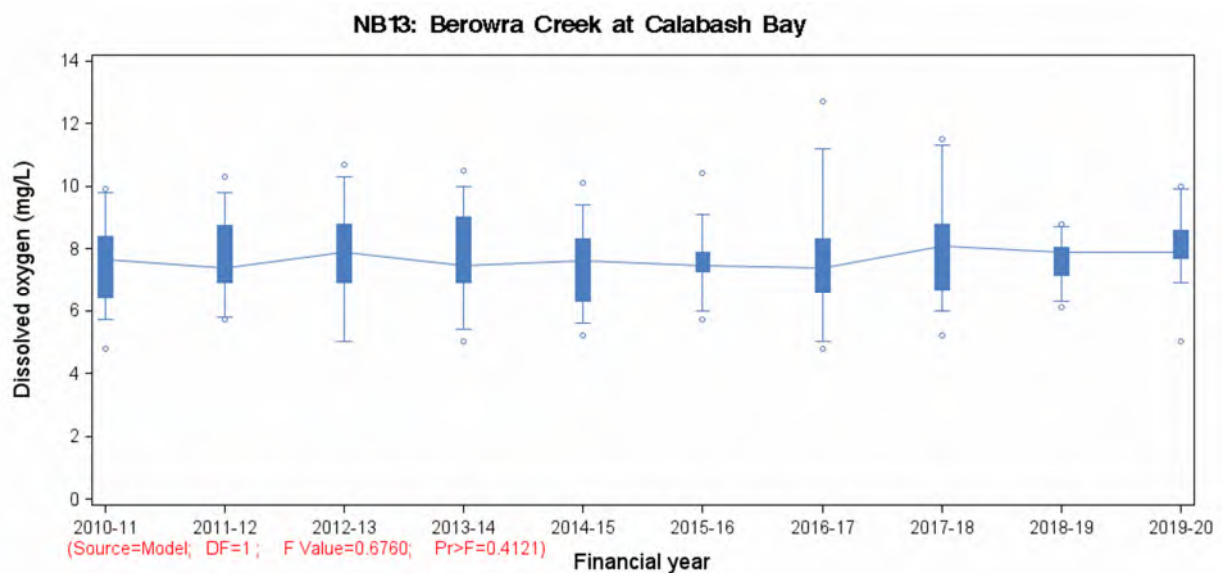
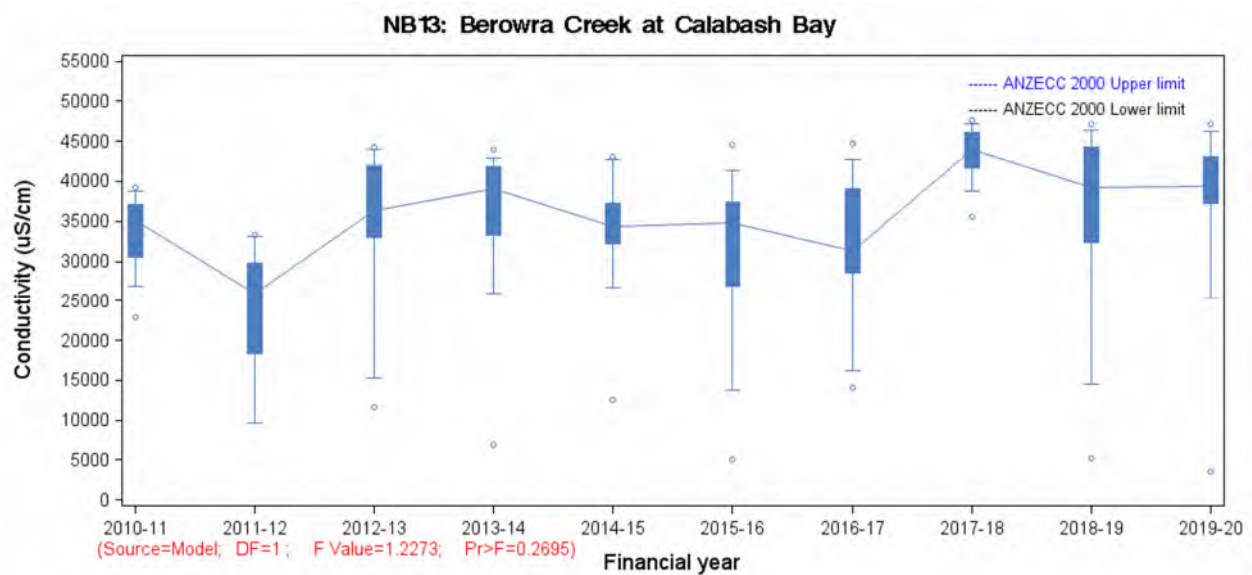


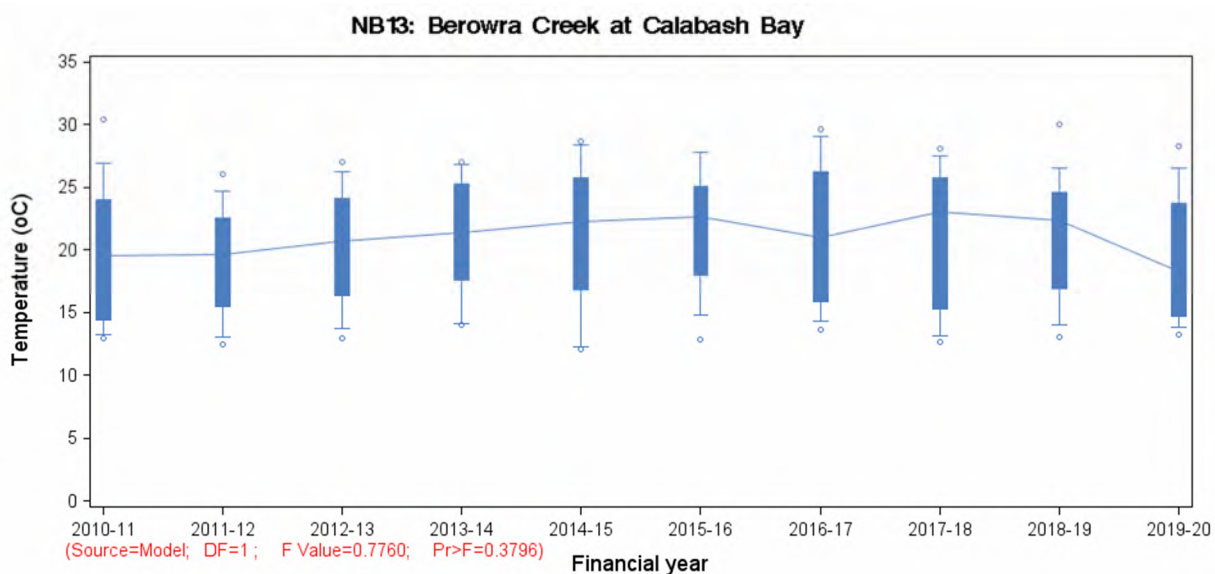
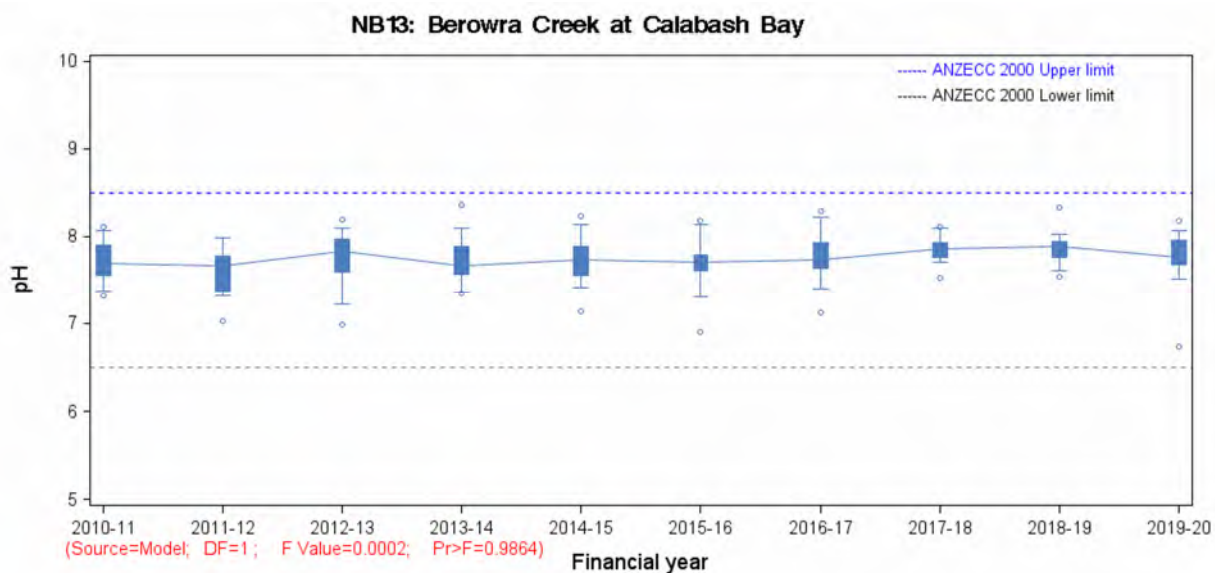
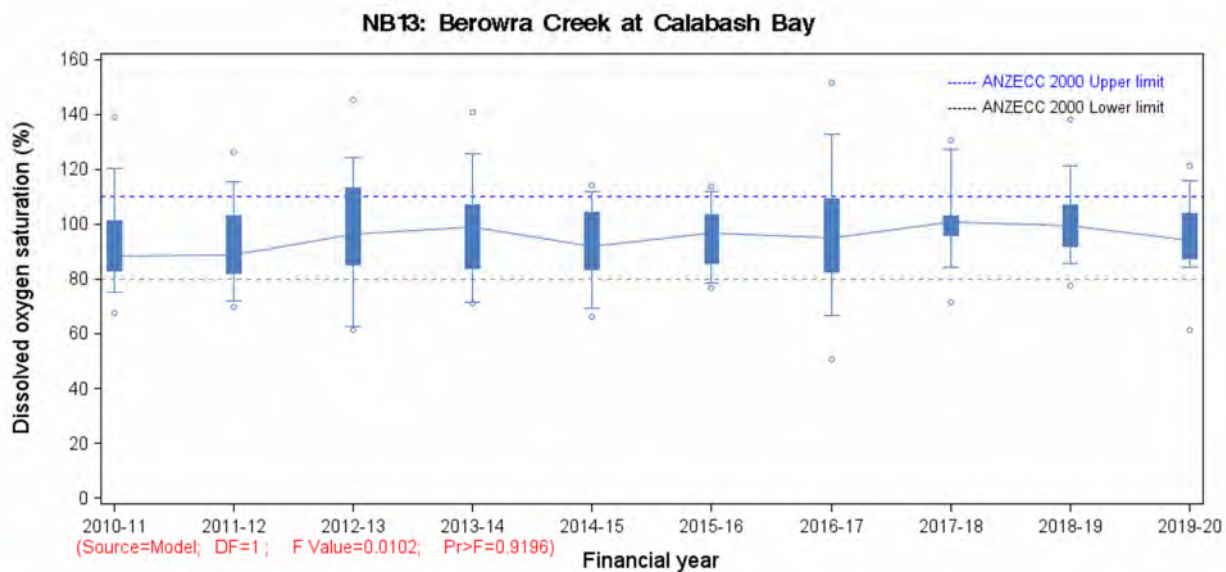
Note: Insufficient data to draw a plot on blue-green algal biovolume

Note: Insufficient data to draw a plot on toxic blue-green algal biovolume

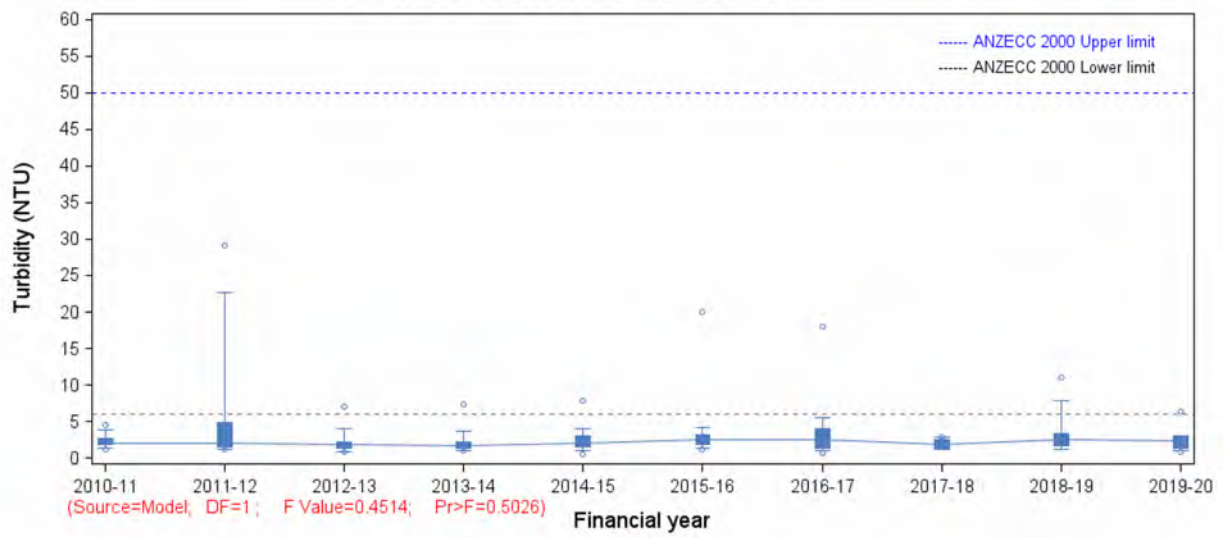
Note: Insufficient data to draw a plot on toxic blue-green algal count

Other physico-chemical analytes

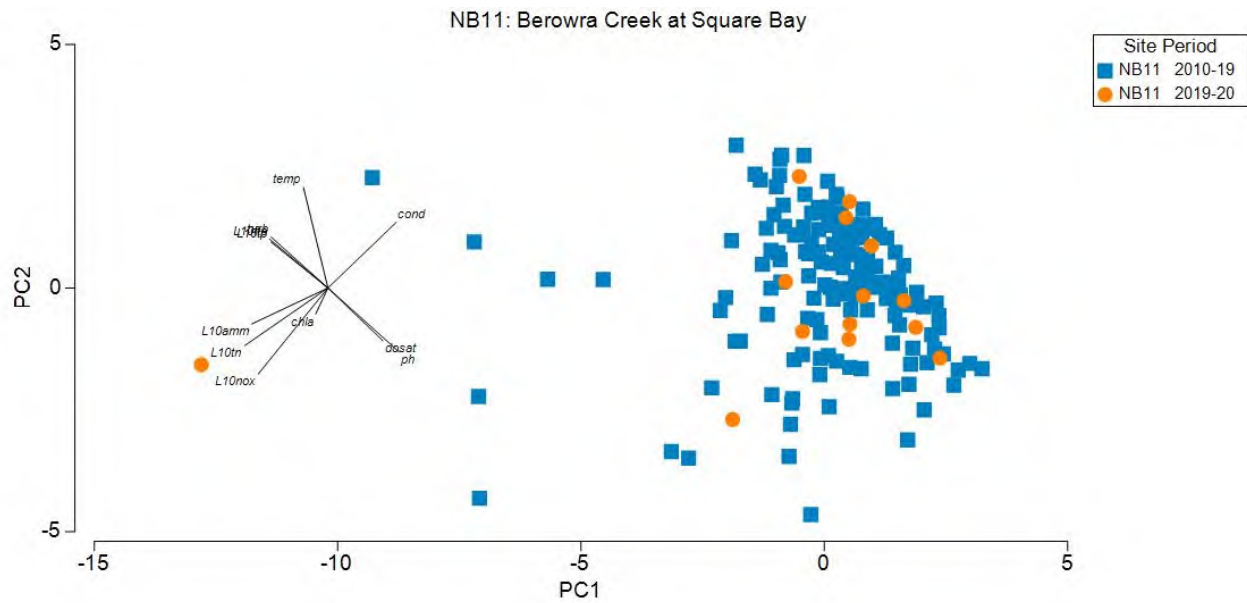




NB13: Berowra Creek at Calabash Bay

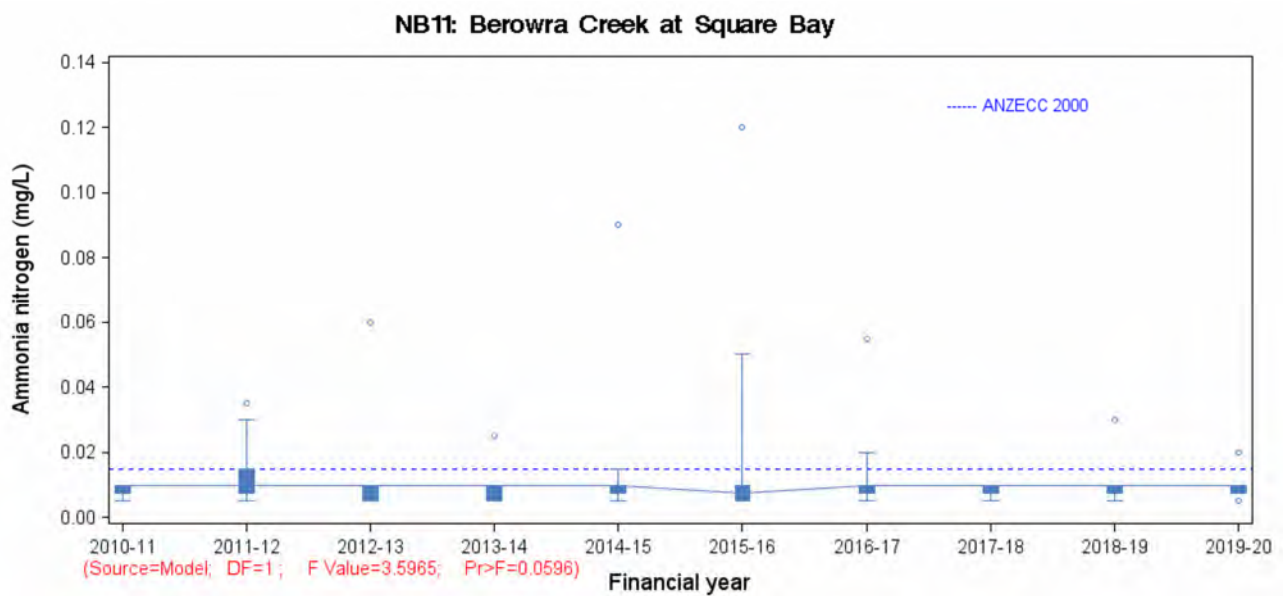


NB11: Berowra Creek off Square Bay

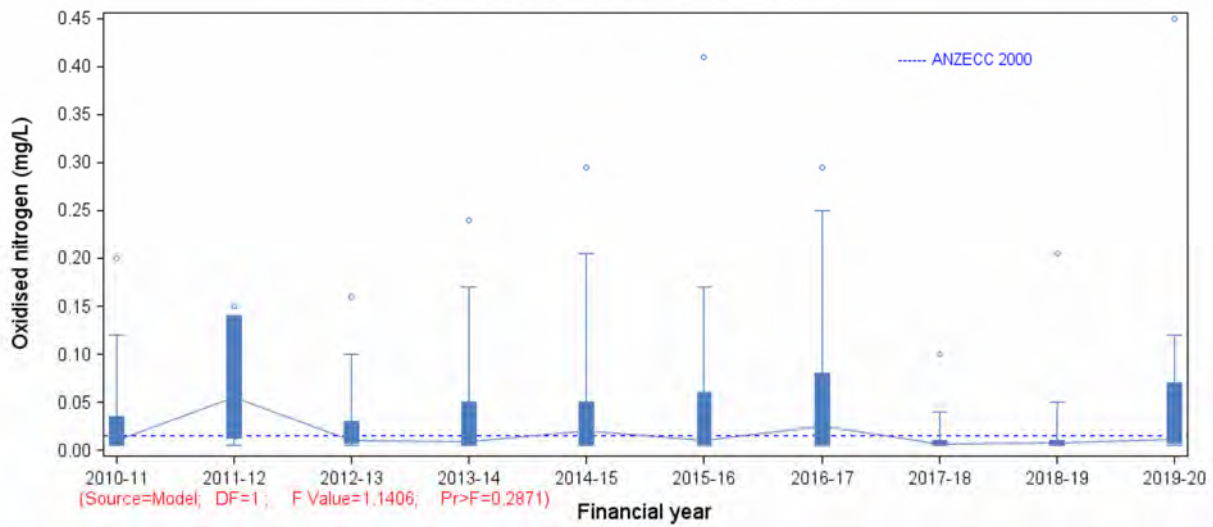


The ordination plot from Principal Components Analysis suggested water quality of Berowra Creek off Square Bay in 2019-20 was generally similar to that recorded in the period 2010 to 2019.

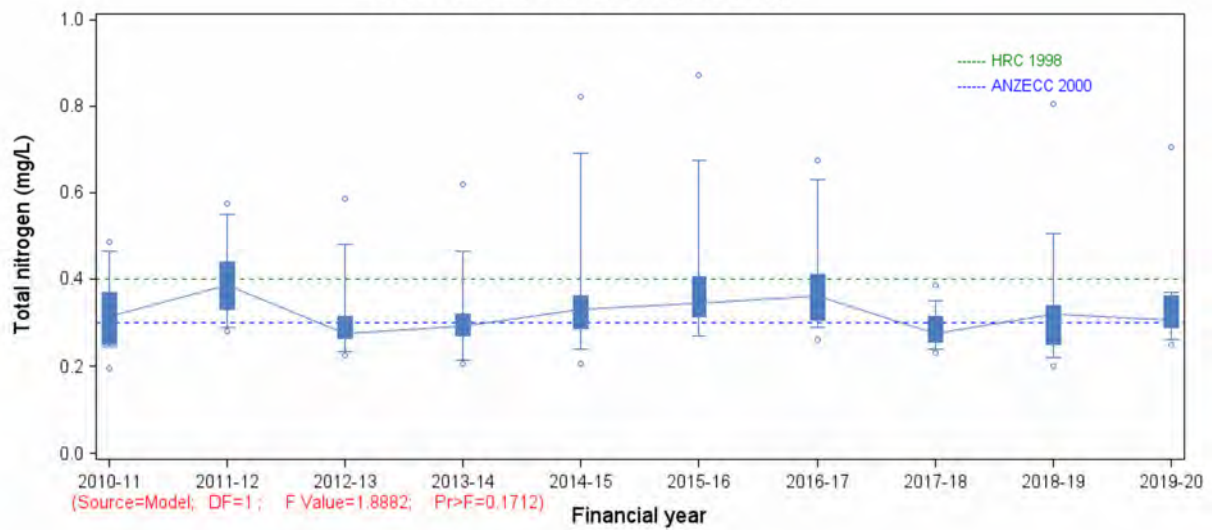
Nutrients, chlorophyll-a and algae



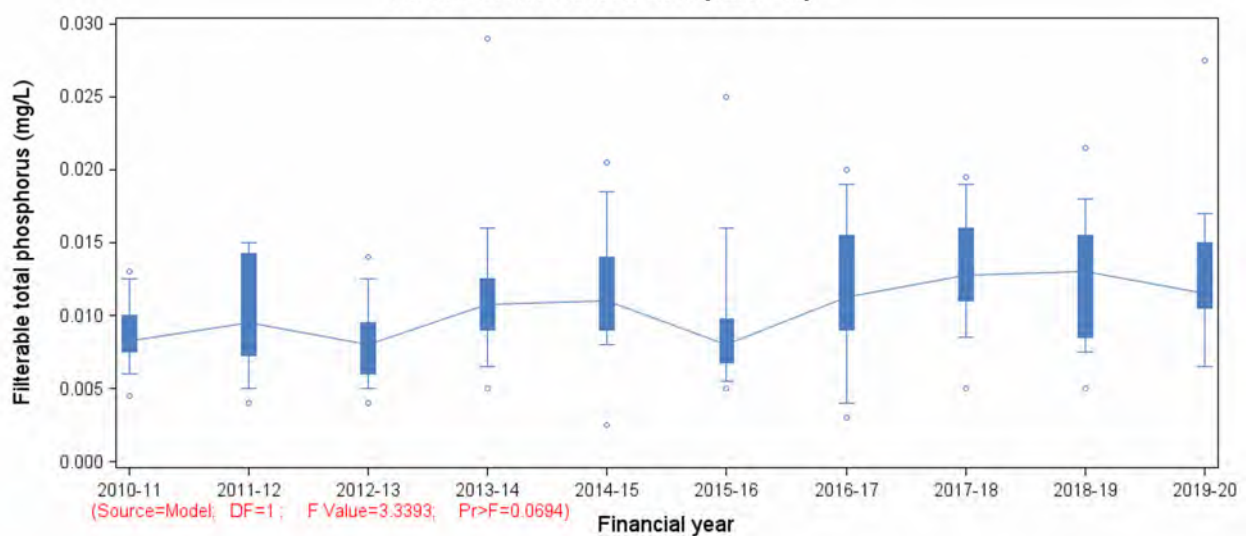
NB11: Berowra Creek at Square Bay



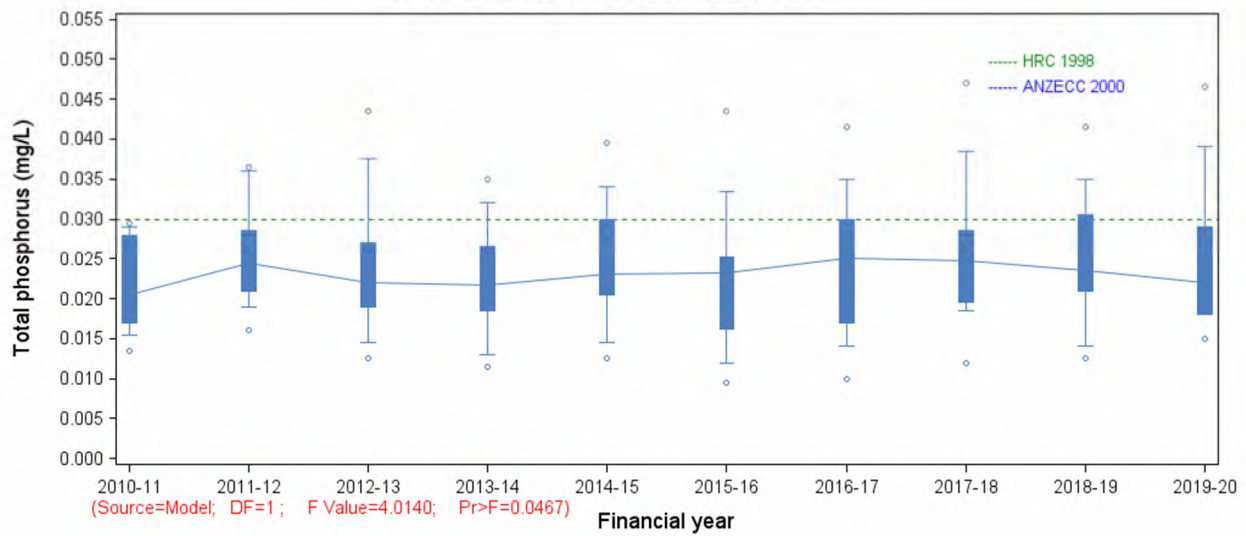
NB11: Berowra Creek at Square Bay



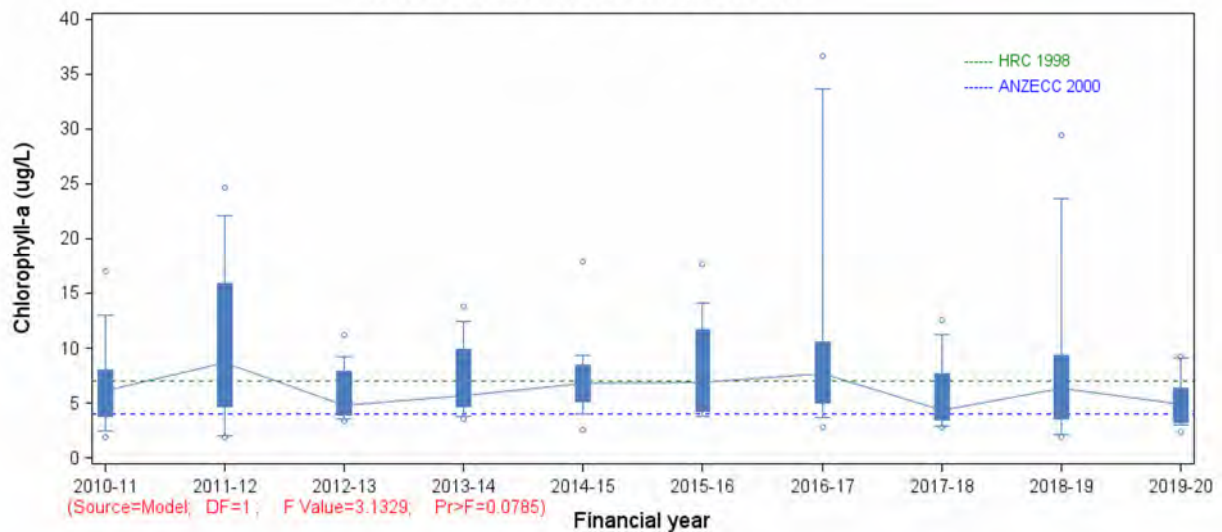
NB11: Berowra Creek at Square Bay



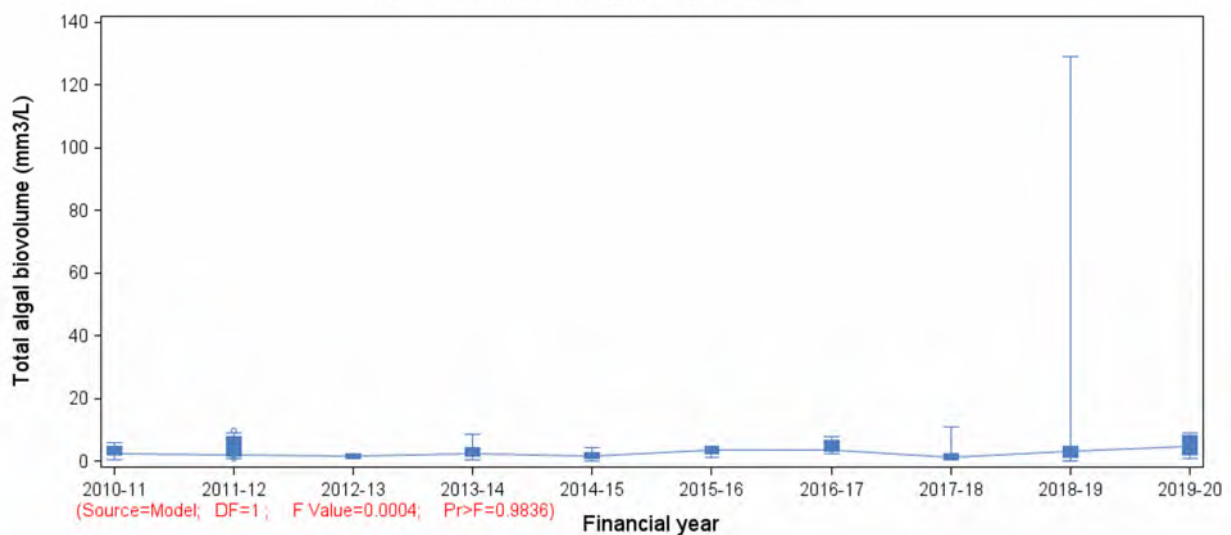
NB11: Berowra Creek at Square Bay



NB11: Berowra Creek at Square Bay



NB11: Berowra Creek at Square Bay

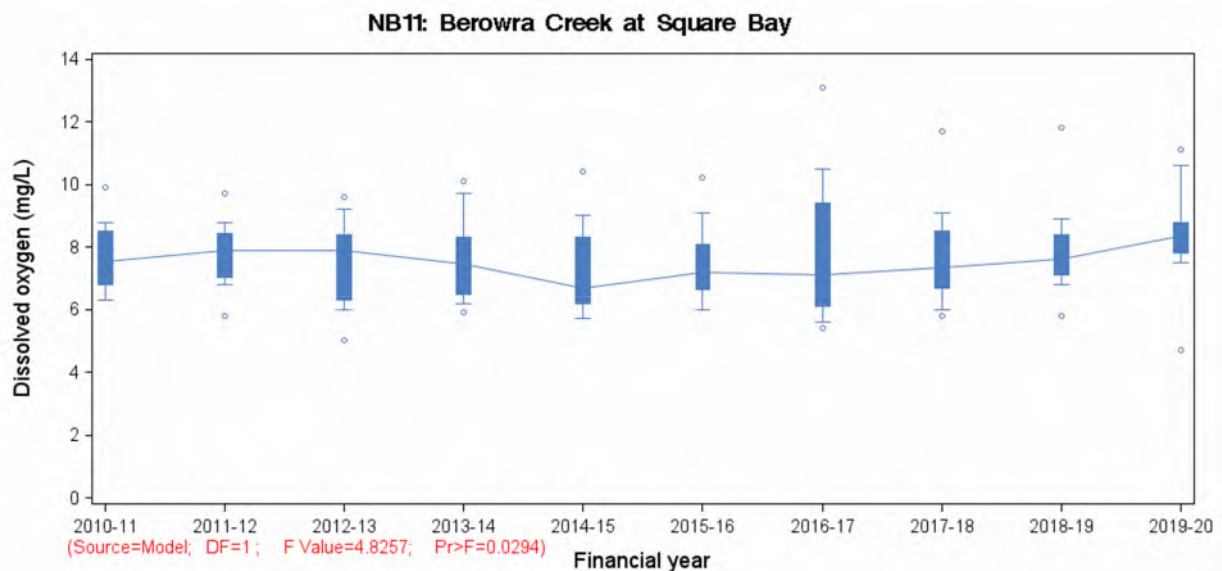
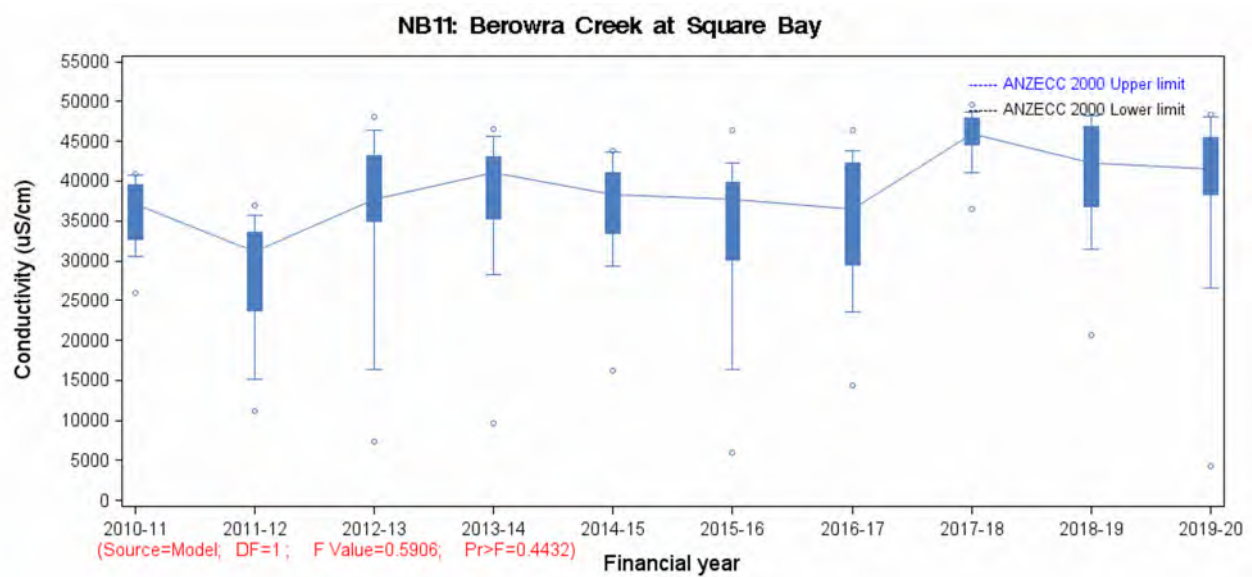


Note: Insufficient data to draw a plot on blue-green algal biovolume

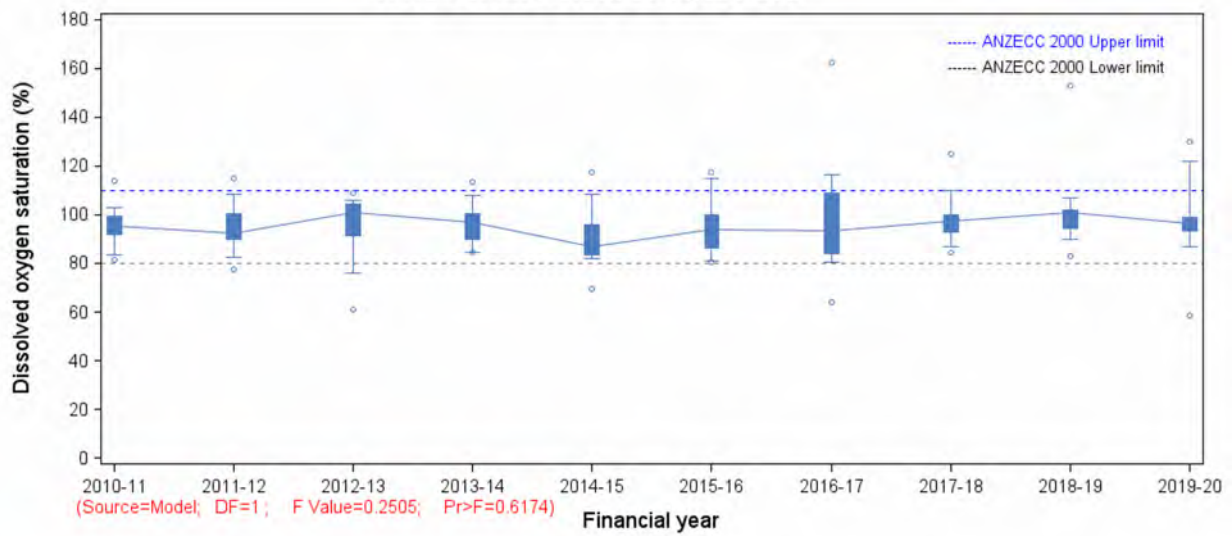
Note: Insufficient data to draw a plot on toxic blue-green algal biovolume

Note: Insufficient data to draw a plot on toxic blue-green algal count

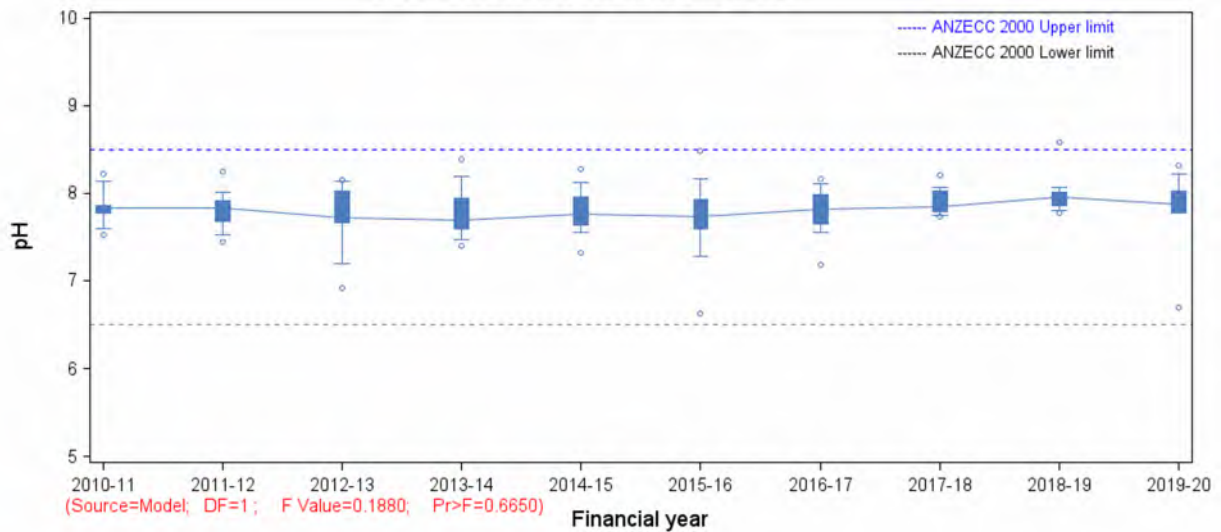
Other physico-chemical analytes



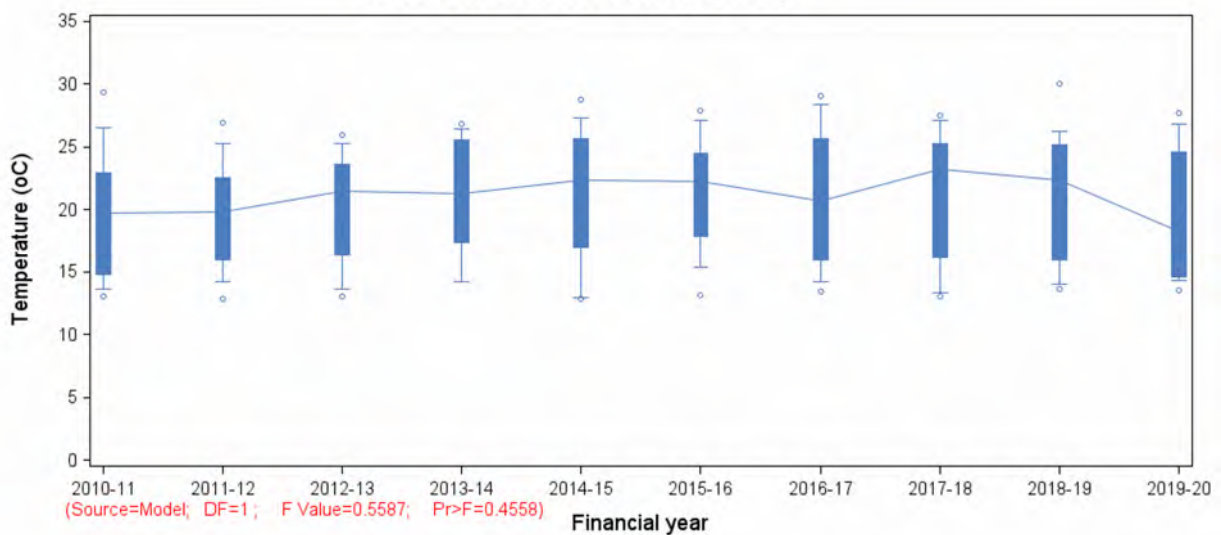
NB11: Berowra Creek at Square Bay



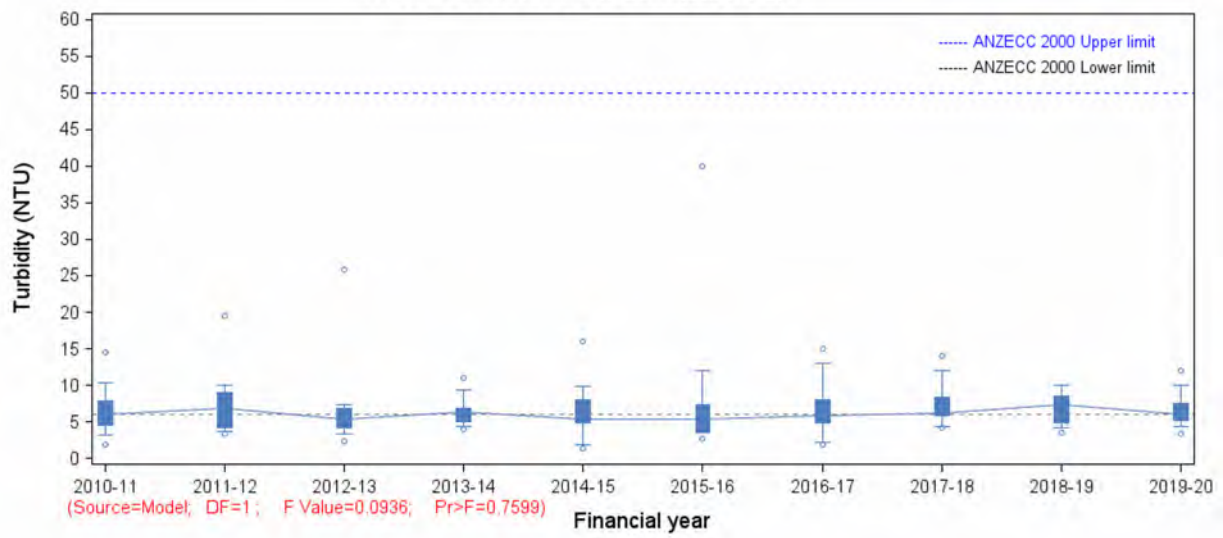
NB11: Berowra Creek at Square Bay



NB11: Berowra Creek at Square Bay



NB11: Berowra Creek at Square Bay





Appendix N : Stream health of Hawkesbury-Nepean River

Stream health in response to discharge from the inland WWTPs are presented in order of upstream to downstream sites:

- Picton WWTP
- West Camden WWTP
- Wallacia WWTP
- Penrith WWTP
- Winmalee WWTP
- North Richmond WWTP
- St Mary's WWTP
- Quakers Hill WWTP
- Riverstone WWTP
- Castle Hill WWTP
- Rouse Hill WWTP
- Hornsby Heights WWTP
- West Hornsby WWTP

Stream health near Picton WWTP

The SIGNAL-SG plot for the Nepean River provided an assessment of stream health. This plot was based on macroinvertebrate identification and counting results expressed as SIGNAL-SG scores and allows a visual comparison of data collected from 2019–20 against that collected between 1995 and 2019. This comparison suggests downstream stream health was maintained at a level comparable to that of the upstream site recorded over the 1995 to 2019 period indicating wastewater discharge from Picton WWTP did not have a measurable negative impact on stream health during 2019-20 (Figure N-1).

A comparison of the upstream-downstream SIGNAL-SG scores for 2019-20 samples under t-tests returned non-significant test outcomes (Table N-1) and confirmed the visual trend for 2019-20.

As no measurable negative impact on downstream stream health was detected, no further data analysis was undertaken.

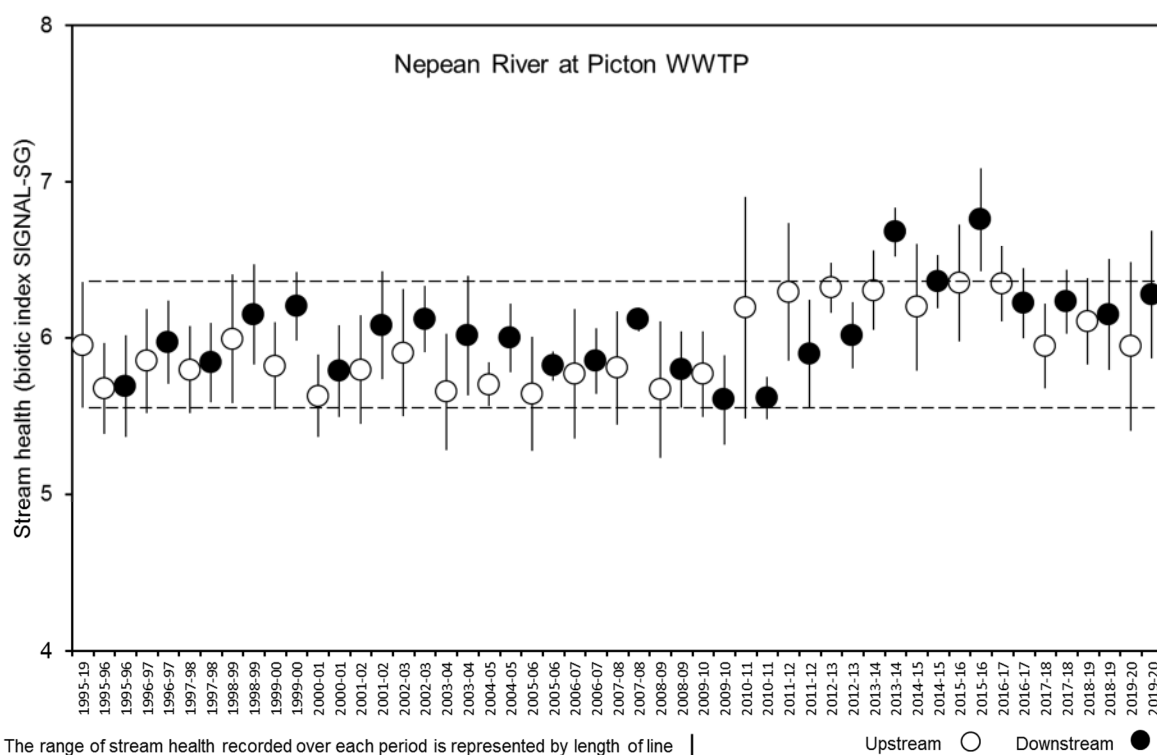


Figure N-1 Stream health of Nepean River near Picton WWTP

Table N-1 t-test of upstream-downstream SIGNAL-SG scores of 2019-20 samples from the Nepean River near Picton WWTP

Method	Variances	DF	t Value	Pr > t
Pooled	Equal	14	1.38	0.1878

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	7	7	1.74	0.4830

Stream health near West Camden WWTP

The SIGNAL-SG plots provided assessments of stream health for both Matahil Creek near West Camden WWTP and in the Nepean River upstream-downstream of the confluence with Matahil Creek. These plots were based upon macroinvertebrate identification and counting results expressed as SIGNAL-SG scores and allows a visual comparison of data collected from 2019–20 against that collected between 2004 to 2019 for the Matahil Creek and 1995 to 2019 for the Nepean River. These visual comparisons suggest downstream stream health was maintained in the Nepean River over 1995 to 2019 (Figure N-3, Table N-3). A localised impact in stream health was indicated for the Matahil Creek in 2019-20 (Figure N-2).

A comparison of the upstream-downstream SIGNAL-SG scores for 2019-20 samples under t-tests returned a significant test outcome for Matahil Creek (Table N-2) and a non-significant test outcome for the Nepean River, which confirmed the visual trends of respective SIGNAL-SG plots (Figure N-2 and Figure N-3).

As a measurable negative impact on downstream stream health was detected on Matahil Creek, further data analysis was undertaken.

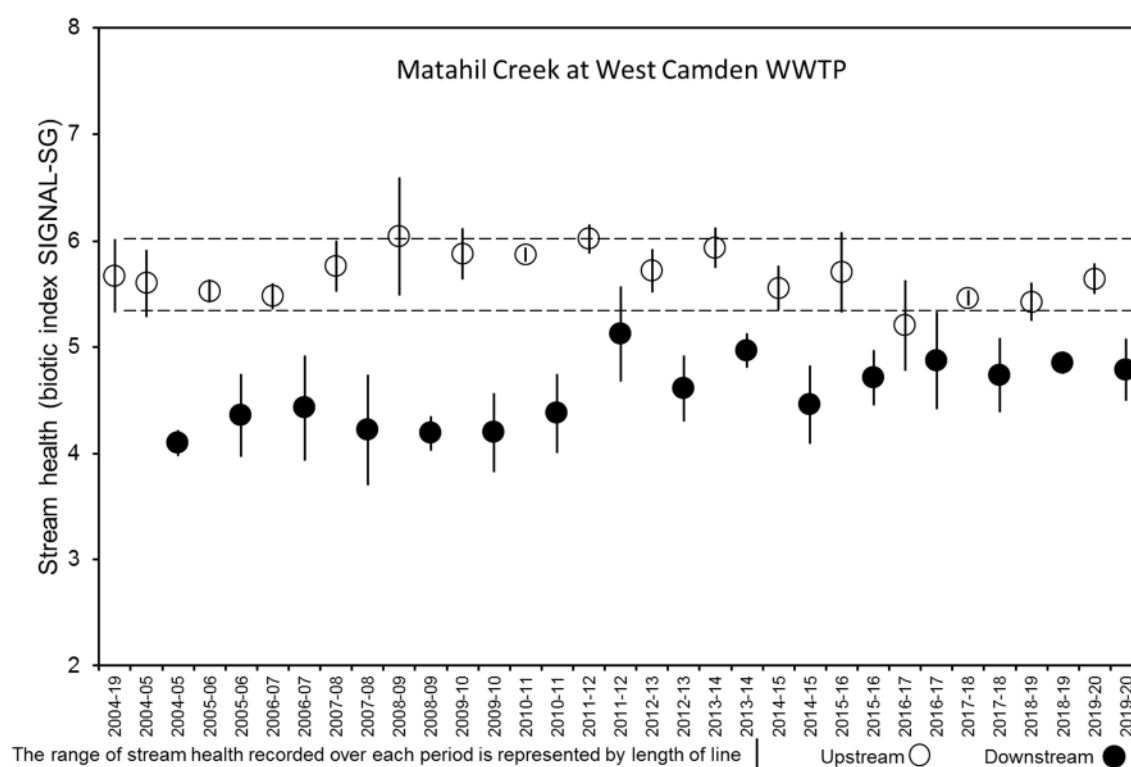


Figure N-2 Stream health of Matahil Creek near West Camden WWTP

Table N-2 t-test of upstream-downstream SIGNAL-SG scores of 2019-20 samples from Matahil Creek near West Camden WWTP

Method	Variances	DF	t Value	Pr > t
Pooled	Equal	7	-4.67	0.0023

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	5	2	4.02	0.4222

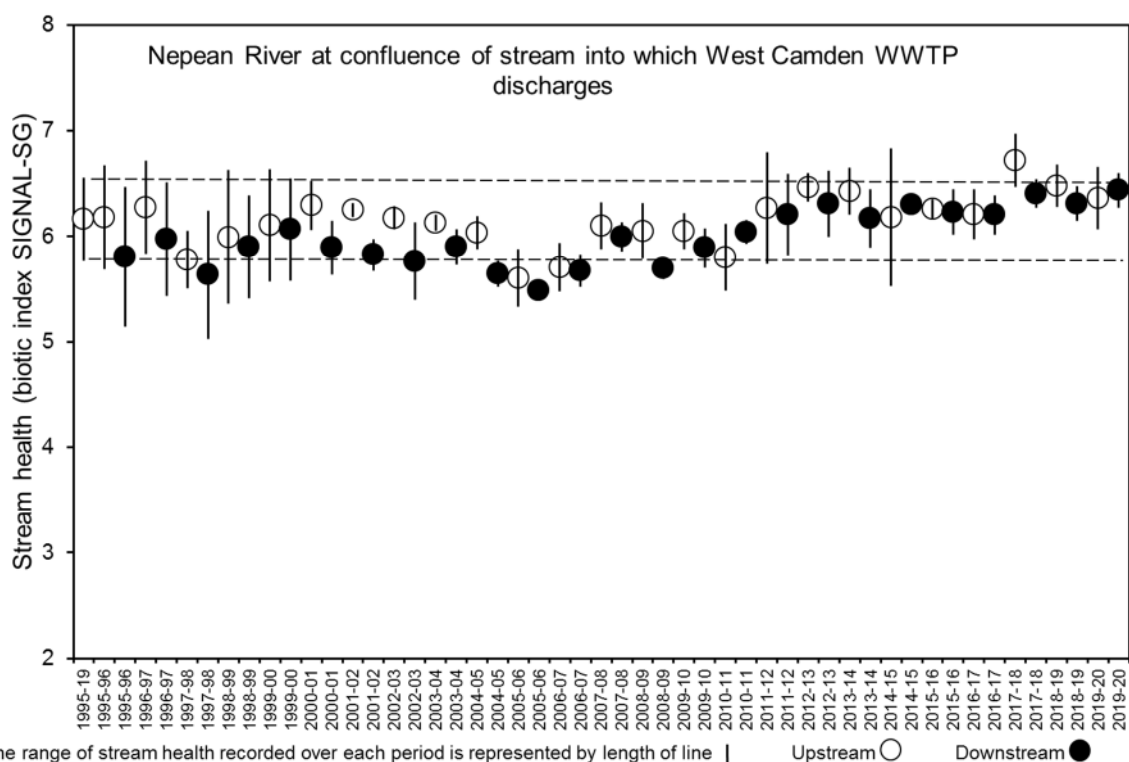


Figure N-3 Stream health of the Nepean River near West Camden WWTP

Table N-3 t-test of upstream-downstream SIGNAL-SG scores of 2019-20 samples from the Nepean River near West Camden WWTP

Method	Variances	DF	t Value	Pr > t
Pooled	Equal	10	0.53	0.6076

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	5	5	3.31	0.2154

Edge habitat samples were collected consistently enough from Matahil Creek to allow multivariate analysis for the monitoring period 2004 to 2020. Distinct groups of samples separated by site were evident for Matahil Creek in the two-dimensional ordination plot (Figure N-4).

The ordination pattern was confirmed in the corresponding tree diagram (dendrogram) from classification analysis as the first division separated all upstream site samples from all downstream site samples (Figure N-5). This initial separation also occurred at a quite low similarity of 12% (Figure N-5) compared with all Nepean River sites samples which exhibited a greater initial similarity level of 37% (Figure N-8).

The clear separation of Matahil Creek sites was also evident in the corresponding shade plot (Figure N-6) where downstream samples displayed less diversity when compared to the upstream site. The shade plot displayed a few taxa in common between the two sites such as the freshwater snail *Physidae Physela*, the caddisfly larvae *Leptoceridae Triplectides* and the non-biting midge larvae *Chironimidae Chironomus*. The corresponding SIGNAL-SG grades showed that dominant taxa that occurred downstream have lower SIGNAL-SG grades than those of the



upstream site (Figure N-6), which is reflected in the separation of site SIGNAL scores displayed in Figure N-2.

The BVSTEP routine was used to find a subset of taxa whose multivariate pattern matched that of the full dataset with 17 taxa identified for the edge habitat (Table N-8) out of 134 taxa. These taxa reflected those taxa which formed the main patterns within the shade plot (Figure N-6).

The PERMDISP analysis indicated a similar pattern of dispersion (spacing between same site samples) for the two sites (Table N-6). This outcome suggests the variability in taxonomic make-up of samples collected over time was at similar levels for both sites through the period tested (2005 to 2020). This result then also implies subsequent results of ANOSIM tests are focused on community structure differences between sites.

The ANOSIM test run on the factor 'Site' returned a high range value ($R = 0.998$; $P = 0.001$) confirming community structure was distinct at each site (Table N-4).

To further explore community structure, hypothesis testing was conducted with PERMANOVA. The PERMANOVA model comprised the fixed factors 'Site' and 'Year'. 'Year' represented samples collected in years between 2005 and 2020. 'Site' had two levels, upstream and downstream. A statistically non-significant 'Site x Year' interaction was returned (Table N-5). This non-significant result allowed us to view the 'Site' and 'Year' results. A statistically non-significant 'Year' result was returned, however 'Site' resulted in a statistically significant result indicating differences exist between the upstream and downstream sites.

A second run of ANOSIM based on Site-period sample groups displayed in above ordination plots returned a significant global R-value at a high level of 0.772 (Table N-7). Pairwise tests indicated the four upstream versus downstream comparisons also had high level R-values (close to or equaling the maximum R-value of 1). In contrast, the same site comparison of the two time periods within each site were non-significant and returned a low level R-values. These pairwise test results suggest clear differences in assemblage structure between upstream and downstream sites, and that each site had a relatively stable community structure through time (Table N-7).

These results suggested downstream community structure in Matahil Creek was consistently altered by wastewater discharge from West Camden WWTP.

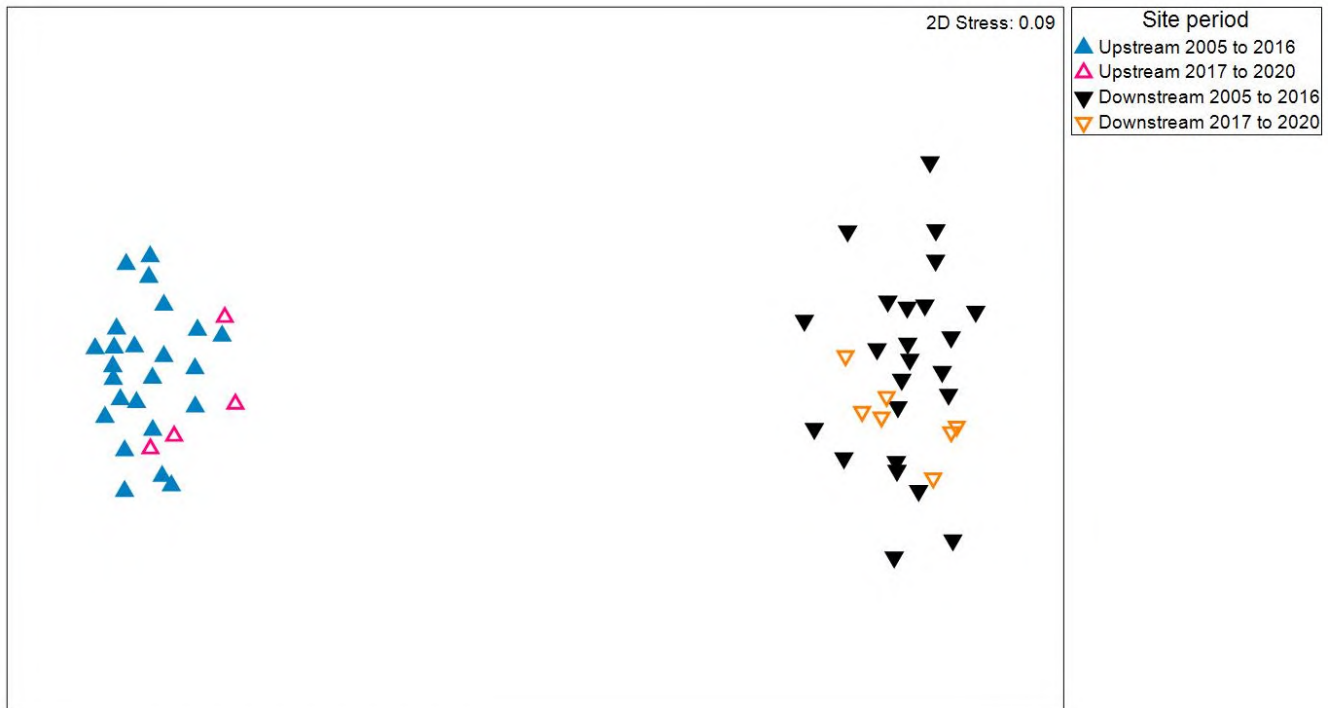


Figure N-4 Two-dimensional ordination plot of freshwater macroinvertebrate edge habitat community structure of Matahil Creek upstream and downstream sites of West Camden WWTP

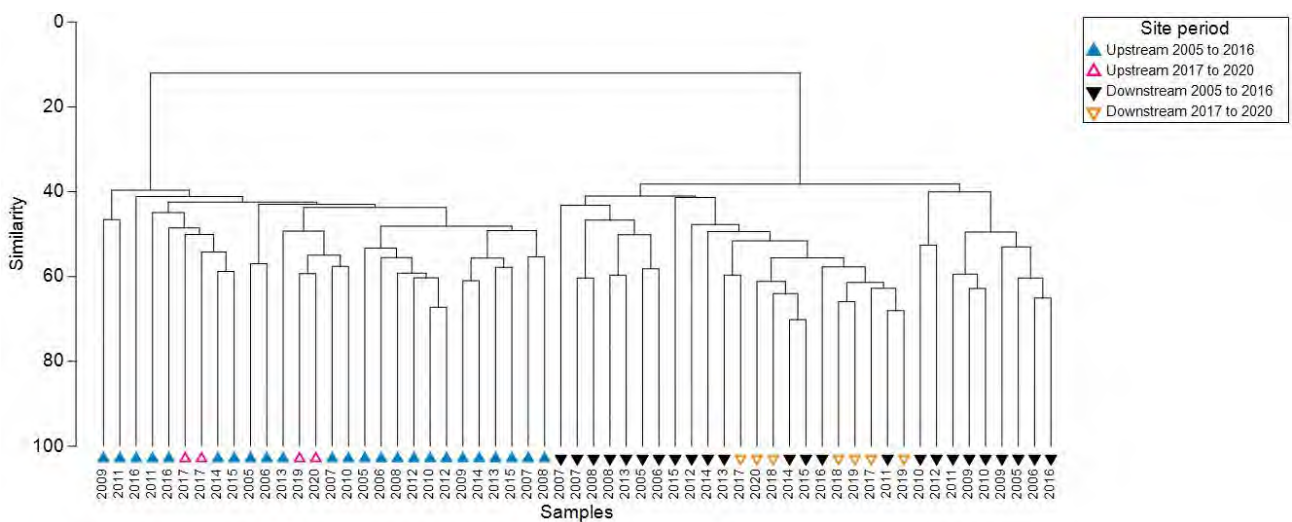


Figure N-5 Tree diagram of freshwater macroinvertebrate edge habitat community structure of Matahil Creek upstream and downstream sites of West Camden WWTP

Table N-4 ANOSIM test of 'Site' factor for edge habitat of Matahil Creek upstream and downstream sites of West Camden WWTP

Tests for differences between unordered Site groups

Global Test

Sample statistic (R): 0.998

Significance level of sample statistic: 0.01%

Number of permutations: 9999 (Random sample from a large number)

Number of permuted statistics greater than or equal to R: 0

Table N-5 PERMANOVA test of 'Site' and 'Year' factors for edge habitat of Matahil Creek upstream and downstream sites of West Camden WWTP

Sums of squares type: Type III (partial)

Fixed effects sum to zero for mixed terms

Permutation method: Permutation of residuals under a reduced model

Number of permutations: 9999

Factors

Name	Type	Levels
Site	Fixed	2
Year	Fixed	16

PERMANOVA table of results

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms
Site	1	63017	63017	41.471	0.0001	9940
Year	15	26642	1776.1	1.1689	0.0625	9750
SitexYear	14	23248	1660.6	1.0928	0.1945	9712
Res	28	42547	1519.5			
Total	58	1.6061E+05				

Estimates of components of variation

Source	Estimate	Sq.root
S(Site)	2254.9	47.486
S(Year)	70.241	8.381
S(SitexYear)	74.799	8.6487
V(Res)	1519.5	38.981

Table N-6 PERMDISP test of 'Site' factor for edge habitat of Matahil Creek upstream and downstream sites of West Camden WWTP

Group factor: Site

Number of permutations: 9999

Number of groups: 2

Number of samples: 59

DEVIATIONS FROM CENTROID

F: 0.31846 df1: 1 df2: 57

P(perm): 0.5806

MEANS AND STANDARD ERRORS

Group	Size	Average	SE
Downstream	31	39.601	1.2212
Upstream	28	38.722	0.92456



Table N-7 ANOSIM test of 'Site period' samples for edge habitat of Matahil Creek upstream and downstream sites of West Camden WWTP

Tests for differences between unordered Site period groups

Global Test

Sample statistic (R): 0.772

Significance level of sample statistic: 0.01%

Number of permutations: 9999 (Random sample from a large number)

Number of permuted statistics greater than or equal to R: 0

Pairwise Tests

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
Downstream 2005 to 2016, Downstream 2017 to 2020	-0.019	56.3	2629575	9999	5632
Downstream 2005 to 2016, Upstream 2005 to 2016	0.998	0.01	Very large	9999	0
Downstream 2005 to 2016, Upstream 2017 to 2020	0.99	0.01	20475	9999	0
Downstream 2017 to 2020, Upstream 2005 to 2016	1	0.01	2629575	9999	0
Downstream 2017 to 2020, Upstream 2017 to 2020	1	0.3	330	330	1
Upstream 2005 to 2016, Upstream 2017 to 2020	0.091	26.1	20475	9999	2604

Table N-8 Genera subset whose multivariate pattern matches full genera set of the edge habitat of Matahil Creek upstream and downstream sites of West Camden WWTP

Subset of 17 (correlation 0.951) genera from edge habitat whose pattern matches that of the full set of 134 genera identified with the same subset found on 9 runs from 50 random start runs. Each run was based on three randomly selected genera. Genera were:

Chironomidae *Chironomus*, Coenagrionidae *Ischnura*, Physidae *Physella*, Belostomatidae *Diplonychus*, Chironomidae *Cricotopus*, Chironomidae *Dicrotendipes*, Chironomidae *Kiefferulus*, Simuliidae *Simulium*, Hydrophilidae *Helochaeres*, Libellulidae *Nannophlebia*, Scyphacidae *Haloniscus*, Tateidae *Potamopyrgus*, Dytiscidae *Necterosoma*, Leptoceridae *Notalina*, Hydrophilidae *Berosus*, Veliidae *Microvelia*, Leptoceridae *Triplectides*

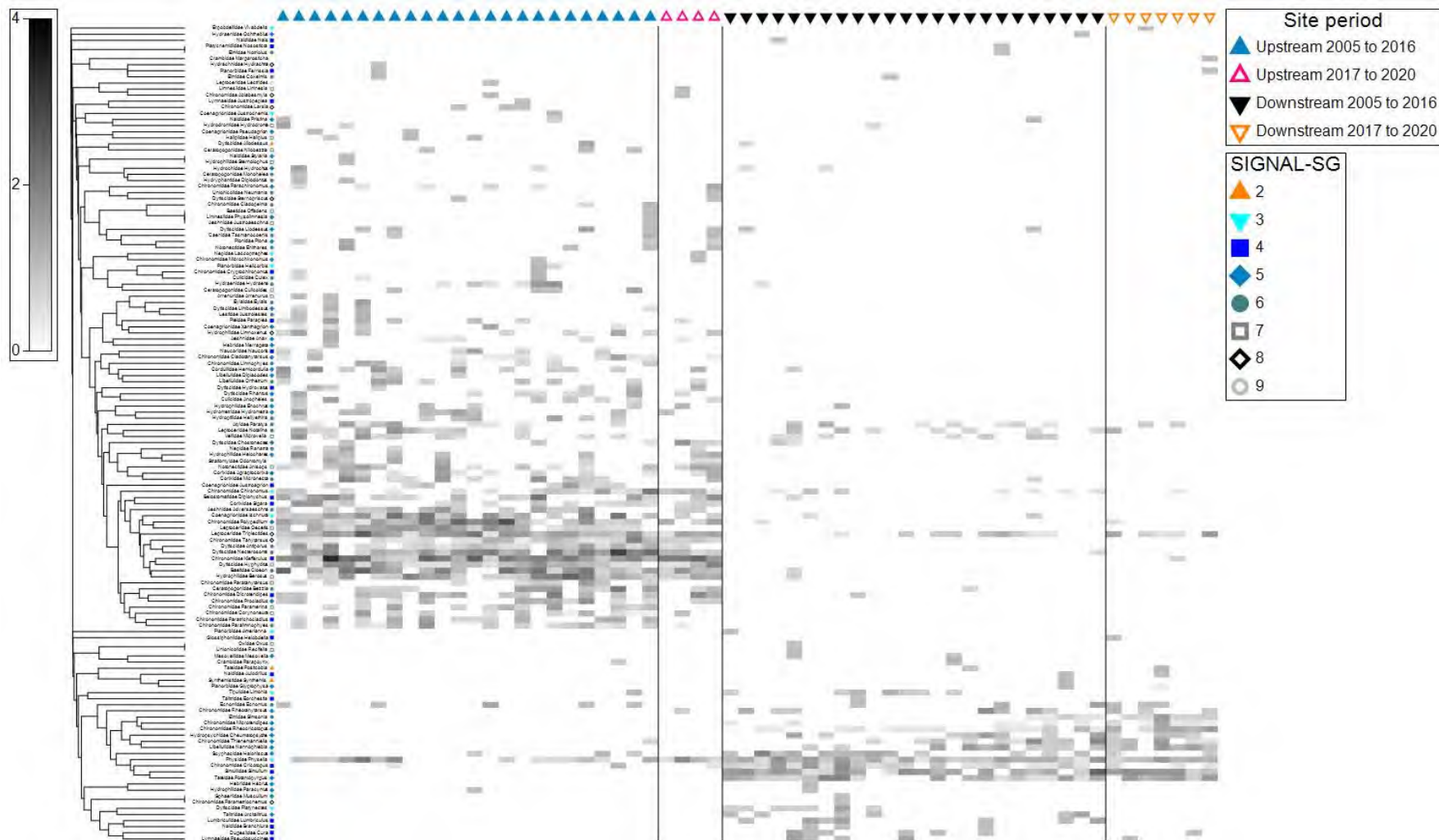


Figure N-6 Shade plot of freshwater macroinvertebrate edge habitat community structure of Matahil Creek upstream and downstream sites of West Camden WWTP



At both upstream and downstream sites on the Nepean-River, edge habitat data was collected consistently enough through time (less sample collection gaps outlined in Volume 1 (Table 3-2) to allow multivariate analysis.

The Nepean River edge habitat data pattern was visually displayed in a three-dimensional nMDS ordination plot, as the two-dimensional plot had a poor (stress) value of 0.26. A stress value of that size potentially represents points being placed almost arbitrarily in two-dimensional space and suggests that there is no clear pattern of upstream downstream differences in the data. Addition of a third dimension provided a more acceptable stress value of 0.19. Data points were colour coded by Site-time periods (Figure N-7). Addition of a third dimension did not reveal a clear separation of groups of upstream and downstream samples in the corresponding ordination plot (Figure N-7).

The lack of a clear upstream downstream site pattern in the ordination plot was confirmed in the corresponding tree diagram (Figure N-8). Initial separation of samples occurred at a moderate level of similarity (37%) (Figure N-8).

The shade plot of the Nepean River edge habitat lacked a distinct site difference in the taxa pattern as seen for the Matahil Creek sites. Rather a less distinct difference between the 2018 to 2020 and 1995 to 2018 periods was apparent for both sites (Figure N-9). Looking at corresponding SIGNAL-SG grades revealed a mix of mid-range grades in both periods for both sites (Figure N-9).

The BVSTEP routine was used to find a subset of taxa whose multivariate pattern matched that of the full dataset with 66 taxa for the edge habitat (Table N-13) out of 178 taxa. This subset of taxa formed the main visual pattern in the respective shade plot (Figure N-9).

The PERMDISP analysis indicated a similar pattern of dispersion (spacing between same site samples) for the two sites (Table N-11). This suggests the variability in taxonomic make-up of samples collected over time was at similar levels for both sites through the period tested (1995 to 2020). This result then also implies subsequent results of ANOSIM tests are focused on community structure differences between sites rather than within.

An ANOSIM test was run on the factor 'Site'. The returned ANOSIM R-value was close to zero (0.108) (Table N-9), implying there was a lack of clearly different taxonomic assemblages present at each site, which was in contrast to the distinct community structure differences shown for Matahil Creek.

To further explore community structure, hypothesis testing was conducted using PERMANOVA (Table N-10). This model included the fixed factors 'Site' and 'Year'. 'Year' represented samples collected in years between 1995 and 2020 whereas 'Site' had two levels, upstream and downstream. A statistically non-significant 'Site x Year' interaction was returned (Table N-10). This non-significant result allowed us to view the 'Site' and 'Year' results. Significant results were returned for 'Site' and 'Year'. The components of variation output indicated 'Year' explained approximately eight times the variation than explained by 'Site' (Table N-10).

A second run of ANOSIM based on Site-period sample groups returned a significant global R-value at a low level of effectively zero (0.083) (Table N-12). Pairwise test outputs were non-significant for five of the six comparisons.

Both SIGNAL-SG and multivariate analysis results suggested downstream community structure in Matahil Creek was consistently altered by wastewater discharge from West Camden WWTP but this impact did not extend as far as the Nepean River.

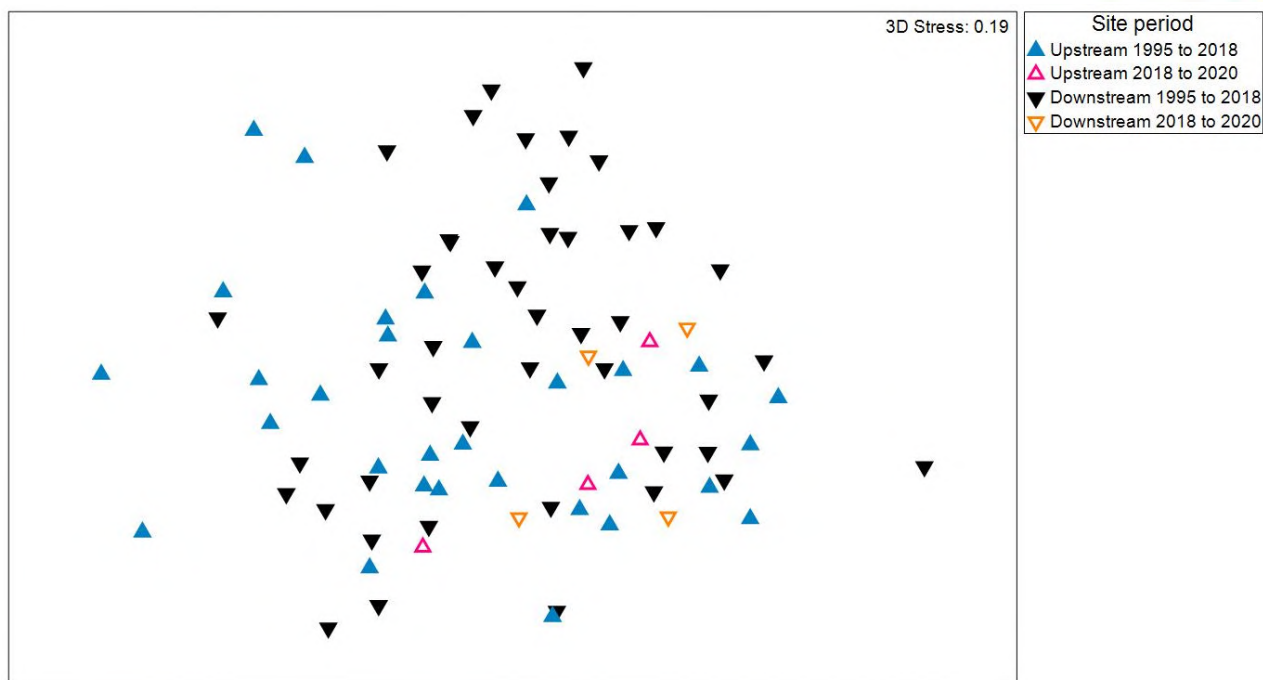


Figure N-7 Dimensions 1 and 2 of three-dimensional ordination plot of freshwater macroinvertebrate edge habitat community structure of sites upstream-downstream of Nepean River at the confluence of Matahil Creek into which West Camden WWTP discharges

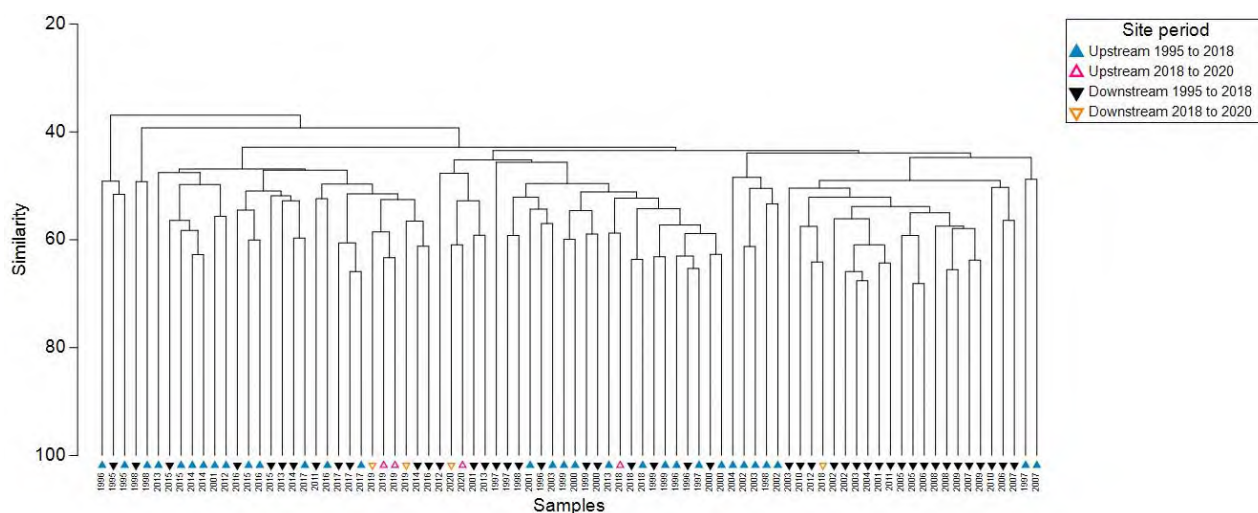


Figure N-8 Tree diagram of freshwater macroinvertebrate edge habitat community structure of sites upstream-downstream of Nepean River at the confluence of Matahil Creek into which West Camden WWTP discharges

Table N-9 ANOSIM test of 'Site' for edge habitat of upstream-downstream sites of Nepean River at the confluence of Matahil Creek into which West Camden WWTP discharges

Tests for differences between unordered Site groups

Global Test

Sample statistic (R): 0.108

Significance level of sample statistic: 0.02%

Number of permutations: 9999 (Random sample from a large number)

Number of permuted statistics greater than or equal to R: 1

Table N-10 PERMANOVA test of 'Site' and 'Year' factors for edge habitat of upstream-downstream sites of Nepean River at the confluence of Matahil Creek into which West Camden WWTP discharges

Sums of squares type: Type III (partial)

Fixed effects sum to zero for mixed terms

Permutation method: Permutation of residuals under a reduced model

Number of permutations: 9999

Factors

Name	Type	Levels
Site	Fixed	2
Year	Fixed	26

PERMANOVA table of results

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms
Site	1	2858.2	2858.2	2.4597	0.0011	9910
Year	25	62030	2481.2	2.1353	0.0001	9618
SitexYear	19	20830	1096.3	0.94346	0.7645	9664
Res	38	44156	1162			
Total	83	1.3121E+05				

Estimates of components of variation

Source	Estimate	Sq.root
S(Site)	50.886	7.1335
S(Year)	414.5	20.359
S(SitexYear)	-36.934	-6.0773
V(Res)	1162	34.088

Table N-11 PERMDISP test of 'Site' for edge habitat of upstream-downstream sites of Nepean River at the confluence of Matahil Creek into which West Camden WWTP discharges

DEVIATIONS FROM CENTROID

F: 0.2946 df1: 1 df2: 82

P(perm): 0.6072

MEANS AND STANDARD ERRORS

Group	Size	Average	SE
Downstream	49	38.341	0.68546
Upstream	35	38.913	0.79396

Table N-12 ANOSIM test of 'Site' period for edge habitat of upstream-downstream sites of Nepean River at the confluence of Matahil Creek into which West Camden WWTP discharges

Tests for differences between unordered Site period groups

Global Test

Sample statistic (R): 0.083

Significance level of sample statistic: 1.6%

Number of permutations: 9999 (Random sample from a large number)

Number of permuted statistics greater than or equal to R: 154

Pairwise Tests

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
Downstream 1995 to 2018, Downstream 2018 to 2020	-0.098	75	211876	9999	7501
Downstream 1995 to 2018, Upstream 1995 to 2018	0.129	0.03	Very large	9999	2
Downstream 1995 to 2018, Upstream 2018 to 2020	-0.064	65.9	211876	9999	6591
Downstream 2018 to 2020, Upstream 1995 to 2018	0.068	30.6	52360	9999	3061
Downstream 2018 to 2020, Upstream 2018 to 2020	-0.063	60	35	35	21
Upstream 1995 to 2018, Upstream 2018 to 2020	0.081	27.9	52360	9999	2787

Table N-13 Genera subset whose multivariate pattern matches full genera set of the edge habitat of upstream-downstream sites of Nepean River at the confluence of Matahil Creek into which West Camden WWTP discharges

Subset of 66 (correlation 0.951) genera from edge habitat whose pattern matches that of the full set of 178 genera identified with the same subset found on two runs from 50 random start runs. Each run was based on three randomly selected genera. Genera were:

Aturidae *Wheenyella*, Coenagrionidae *Ischnura*, Physidae *Physella*, Chironomidae *Cricotopus*, Chironomidae *Cryptochironomus*, Chironomidae *Dicrotendipes*, Corbiculidae *Corbicula*, DugesIIDae *Cura*, Glossiphoniidae *Helobdella*, Lymnaeidae *Pseudosuccinea*, Planorbidae *Gyraulus*, Platycnemididae *Nososticta*, Pleidae *Paraplea*, Chironomidae *Cladotanytarsus*, Chironomidae *Microtendipes*, Chironomidae *Parachironomus*, Chironomidae *Polypedilum*, Chironomidae *Procladius*, Coenagrionidae *Pseudagrion*, Corduliidae *Hemicordulia*, Hydrophilidae *Helochares*, Isostictidae *Rhadinosticta*, Libellulidae *Diplacodes*, Libellulidae *Nannophlebia*, Limnesiidae *Physolimnesia*, Atyidae *Paratya*, Baetidae *Cloeon*, Caenidae *Tasmanocoenis*, Ceratopogonidae *Bezzia*, Ceratopogonidae *Monohalea*, Dytiscidae *Necterosoma*, Ecnomidae *Ecnomus*, Elmidae *Coxelmis*, Elmidae *Ovolara*, Gomphidae *Austrogomphus*, Leptoceridae *Notalina*, Corixidae *Micronecta*, Unionicolidae *Unionicola*, Chironomidae *Coelopynia*, Chironomidae *Corynoneura*, Chironomidae *Parakiefferiella*, Chironomidae *Paramerina*, Chironomidae *Paratanytarsus*, Chironomidae *Riethia*, Elmidae *Hydora*, Hydrodromidae *Hydrodroma*, Hydrophilidae *Berosus*, Leptoceridae *Oecetis*, Leptoceridae *Triaenodes*, Limnesiidae *Limnesia*, Mideopsidae *Gretacarus*, Oxidae *Oxus*, Unionicolidae *Koenikea*, Unionicolidae *Recifella*, Veliidae *Microvelia*, Calamoceratidae *Anisocentropus*, Chironomidae *Ablabesmyia*, Chironomidae *Larsia*, Chironomidae *Tanytarsus*, Dytiscidae *Sternopriscus*, Elmidae *Austrolimnius*, Hygrobatidae *Coaustraliobates*, Leptoceridae *Triplectides*, Oxidae *Frontipoda*, Ecnomidae *Ecnomina*, Stratiomyidae *Odontomyia*.

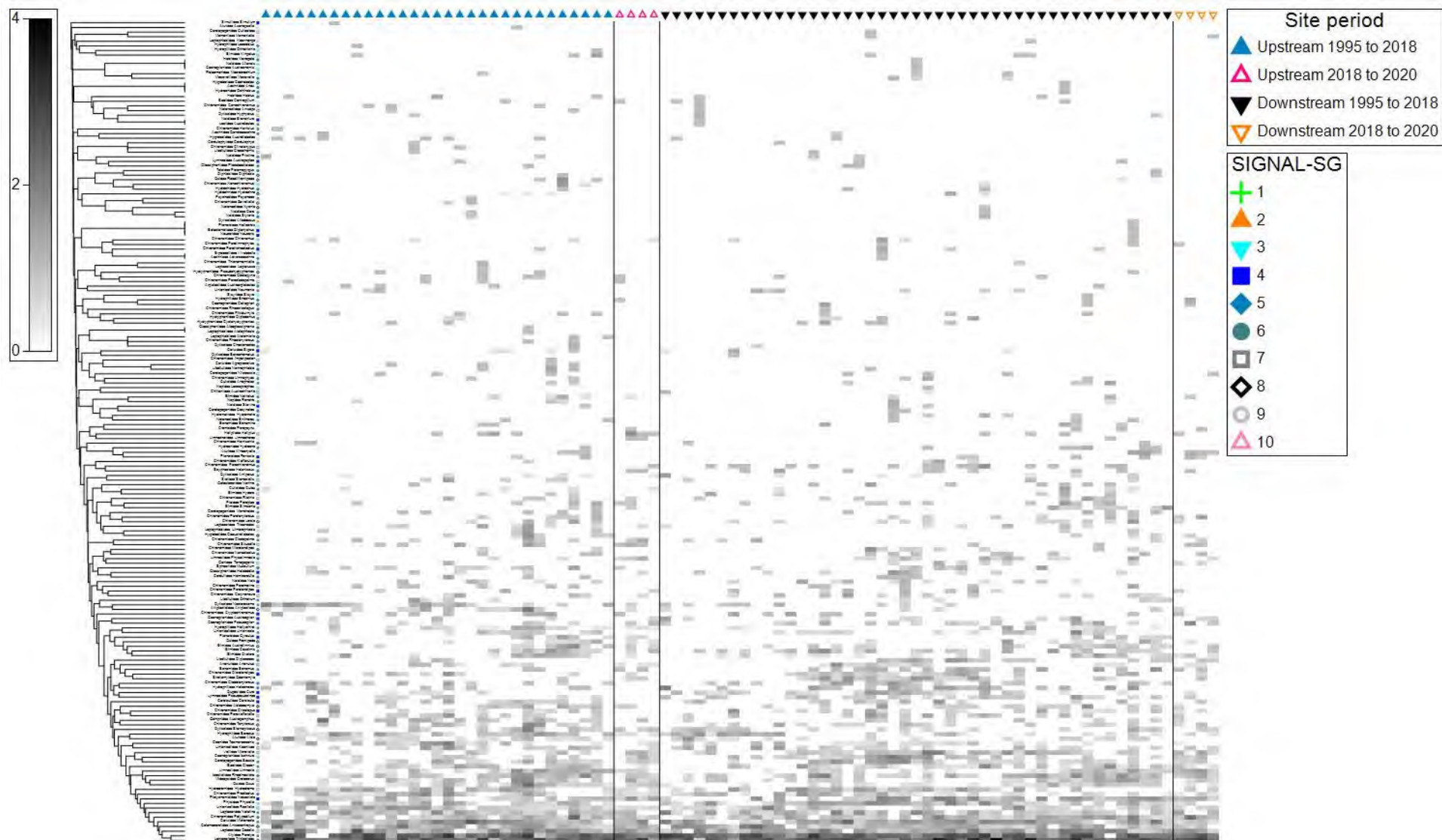


Figure N-9 Shade plot of freshwater macroinvertebrate edge habitat community structure of upstream-downstream sites of Nepean River at the confluence of Matahil Creek into which West Camden WWTP discharges

Stream health near Wallacia WWTP

The SIGNAL-SG plot for the Warragamba River provided an assessment of stream health. This plot was based on macroinvertebrate identification and counting results expressed as SIGNAL-SG scores and allows a visual comparison of data collected from 2019–20 against that collected between 2008 and 2019. This comparison suggests downstream stream health was maintained at a level comparable to that of the upstream site indicating wastewater discharge from Wallacia WWTP did not have a measurable impact on stream health during 2019-20 (Figure N-10).

A comparison of the upstream-downstream SIGNAL-SG scores for 2019-20 samples under a t-test returned a non-significant test outcome (Table N-14) and confirmed the visual trend.

As no measurable impact on downstream stream health was detected, no further data analysis was undertaken.

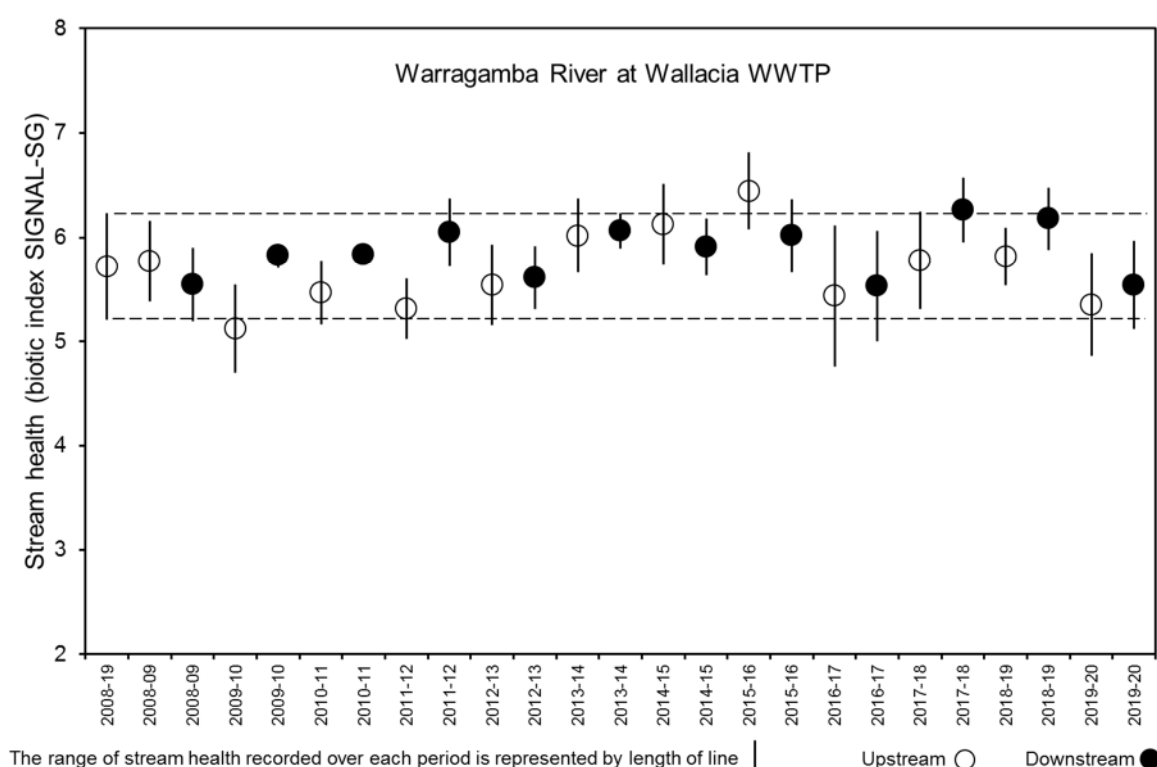


Figure N-10 Stream health of Warragamba River near Wallacia WWTP

Table N-14 t-test of upstream-downstream SIGNAL-SG scores of 2019-20 samples from the Warragamba River near Wallacia WWTP

Method	Variances	DF	t Value	Pr > t
Pooled	Equal	12	0.76	0.4598

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	6	6	1.36	0.7176

Stream health near Penrith WWTP

The SIGNAL-SG plots provided assessments of stream health for both Boundary Creek near Penrith WWTP and the Nepean River upstream-downstream of the confluence with Boundary Creek. These plots were based on macroinvertebrate identification and counting results expressed as SIGNAL-SG scores and allows a visual comparison of data collected from 2019–20 against that collected between 2003 to 2019 for the Boundary Creek sites and 1995 to 2019 for the Nepean River sites. These visual comparisons suggest downstream stream health was maintained at least at a level comparable to that of the upstream site indicating that the wastewater discharge from the Penrith WWTP did not have a measurable negative impact on stream health of either Boundary Creek (Figure N-11) or the Nepean River during 2019-20 (Figure N-12).

A comparison of the upstream-downstream SIGNAL-SG scores for 2019-20 samples under t-tests returned a non-significant test outcome for the Nepean River comparison (Table N-16) as well as the Boundary Creek comparison (Table N-15). As no measurable negative impact on downstream stream health was detected on either Boundary Creek or the Nepean River, no further data analysis was undertaken.

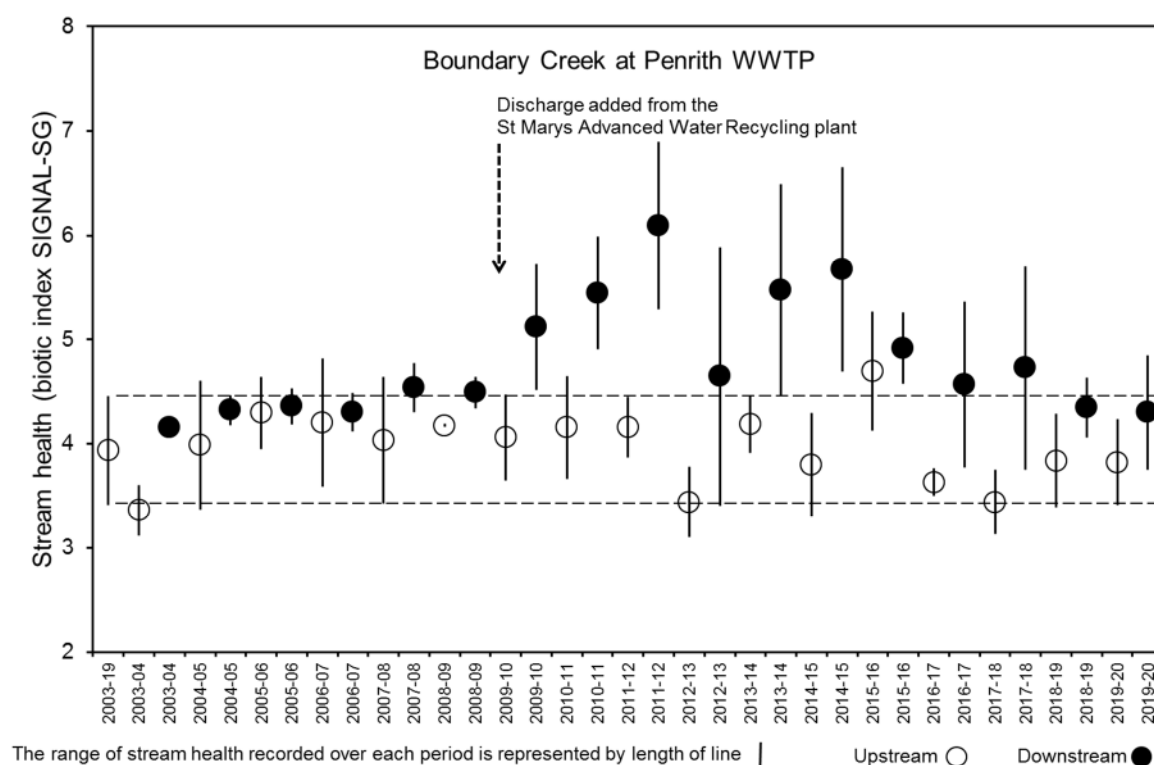


Figure N-11 Stream health of Boundary Creek near Penrith WWTP

Table N-15 t-test of upstream-downstream SIGNAL-SG scores of 2019-20 samples from Boundary Creek near Penrith WWTP

Method	Variances	DF	t Value	Pr > t
Pooled	Equal	10	1.70	0.1200

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	5	5	1.77	0.5457

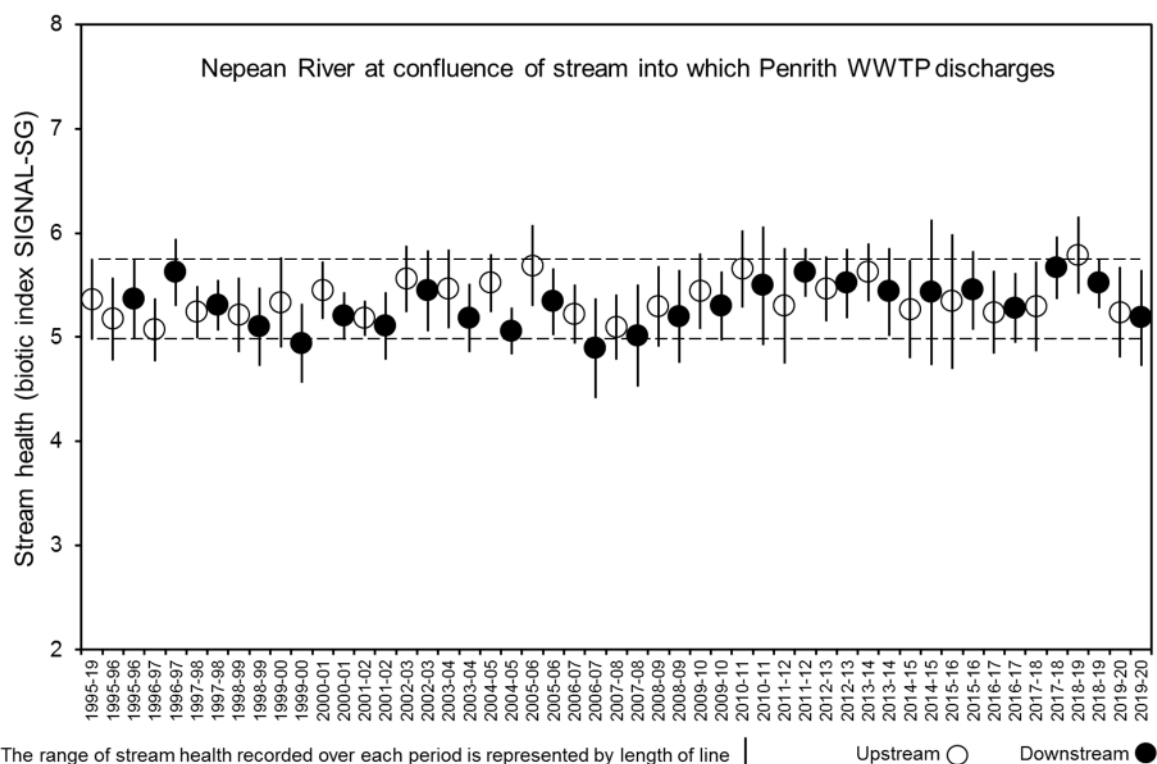


Figure N-12 Stream health of the Nepean River upstream-downstream of the confluence of Boundary Creek near Penrith WWTP

Table N-16 t-test of upstream-downstream SIGNAL-SG scores of 2019-20 samples from the Nepean River near Penrith WWTP

Method	Variances	DF	t Value	Pr > t
Pooled	Equal	10	-0.21	0.8408

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	5	5	1.11	0.9116

Stream health and community structure of the unnamed creek and the Nepean River near Winmalee WWTP

The SIGNAL-SG plots provided assessments of stream health for both the unnamed creek near Winmalee WWTP and in the Nepean River situated upstream-downstream of the confluence with the unnamed creek. These plots were based on macroinvertebrate identification and counting results expressed as SIGNAL-SG scores and allows a visual comparison of data collected from 2019–20 against that collected between 2004 to 2019 for the unnamed creek and 1995 to 2019 for the Nepean River. These visual comparisons suggest downstream stream health was maintained in the Nepean River (Figure N-14) while stream health for the unnamed creek 0.3 km site remained at a relatively high level that overlapped the range of stream health observed for the 3 km downstream site that fell within the range observed over the 2004 to 2019 period (Figure N-13).

A comparison of the upstream-downstream SIGNAL-SG scores for 2019-20 samples under t-tests returned non-significant test outcomes for the Nepean River comparison (Table N-18) and the unnamed creek comparison (Table N-17).

As the non-significant t-test outcome for the unnamed creek was somewhat atypical to past year results, and an impact on unnamed creek has been routinely recorded in the past, further data analysis was undertaken.

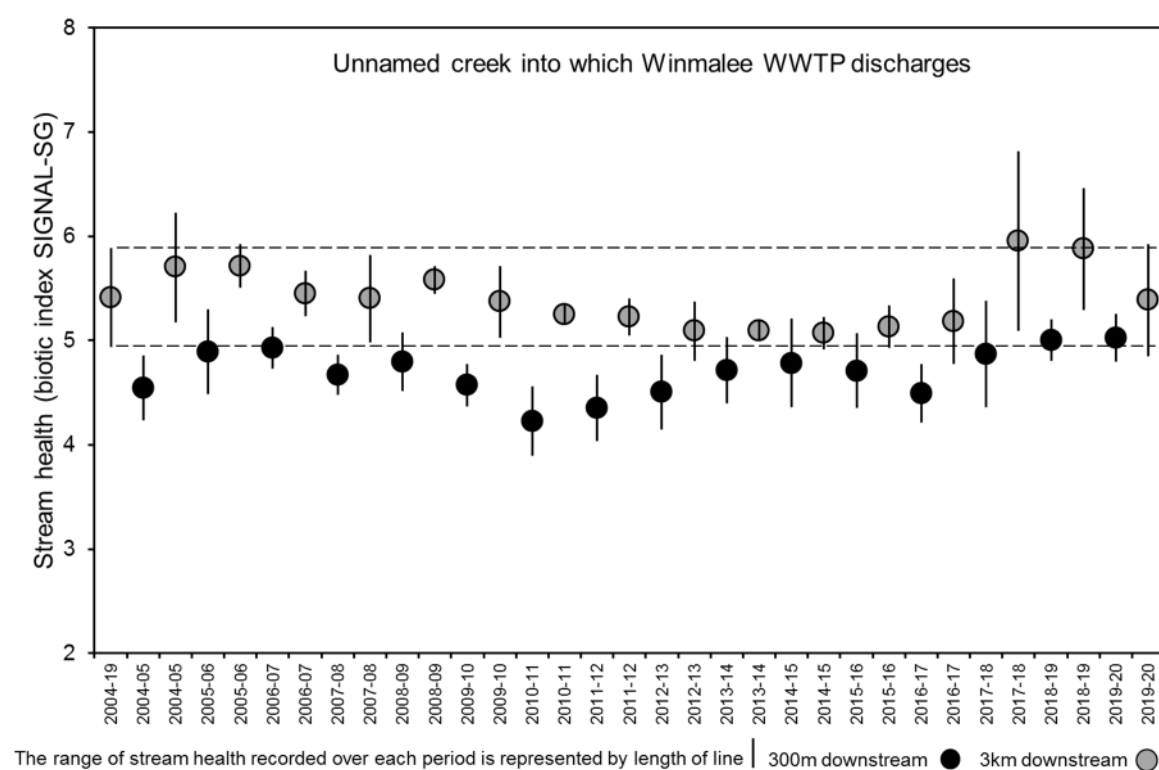


Figure N-13 Stream health of unnamed creek below Winmalee WWTP for two downstream sites

Table N-17 t-test of both downstream site SIGNAL-SG scores from 2019-20 for unnamed creek below Winmalee WWTP

Method	Variances	DF	t Value	Pr > t
Pooled	Equal	10	1.52	0.1594

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	5	5	5.55	0.0833

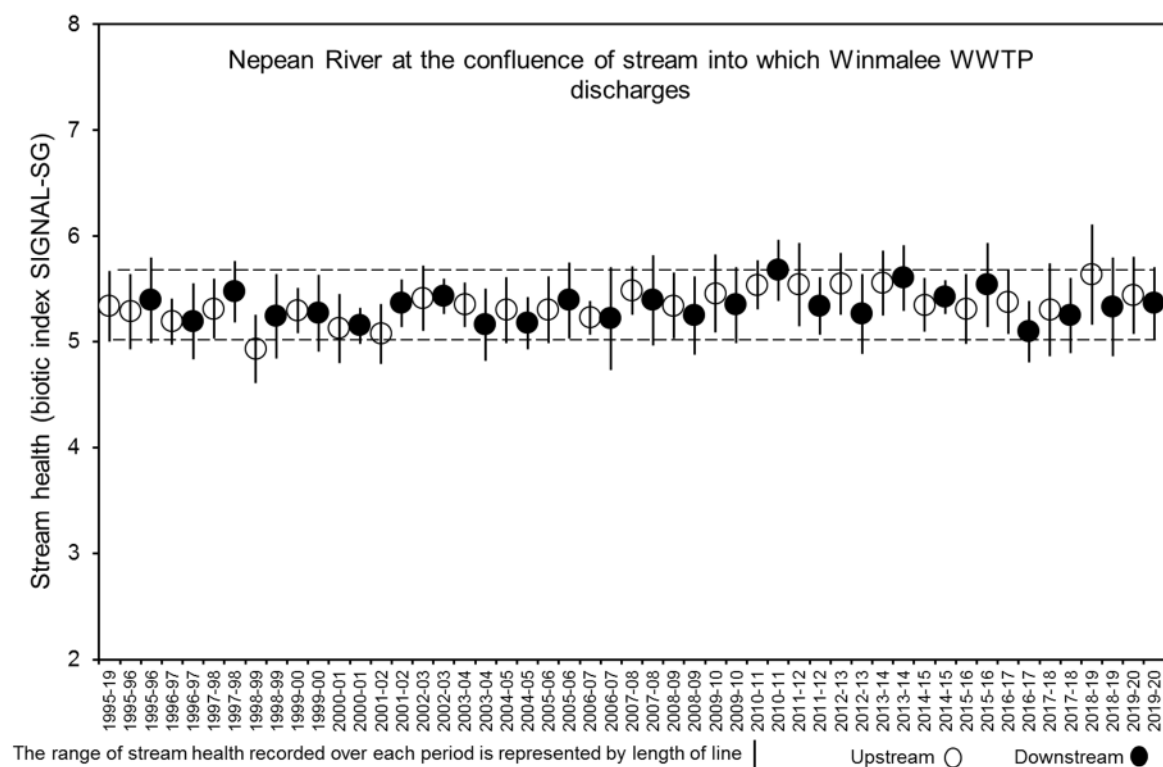


Figure N-14 Stream health of the Nepean River near Winmalee WWTP

Table N-18 t-test of upstream-downstream SIGNAL-SG scores from 2019-20 for the Nepean River near Winmalee WWTP

Method	Variances	DF	t Value	Pr > t
Pooled	Equal	14	-0.42	0.6773

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	7	7	1.17	0.8372



As the unnamed creek has no flow upstream of Winmalee WWTP under dry weather conditions, both sampling sites were situated downstream of the WWTP. The first site is located 0.3 km downstream of the WWTP, while the second downstream site is situated 3 km downstream of the WWTP in a natural bushland catchment that lacks other anthropogenic influences. Both edge and riffle habitat data were collected consistently at both downstream sites on the same sampling occasions to allow multivariate analysis for the monitoring period of 2004 to 2020. Samples from each habitat were analysed separately.

Distinct groups of samples were evident in the three-dimensional ordination plot of edge habitat of the unnamed creek (Figure N-15). The n-MDS ordination pattern was confirmed in the corresponding tree diagram (Figure N-17) from classification analysis where the first and second divisions separated the 2018 to 2020 period samples, whereas the fourth division separated most 0.3 km downstream samples from most 3 km downstream samples (Figure N-17). Despite not showing the early separation between time periods, the riffle habitat showed a similar split between sites at around the third separation level in the corresponding tree diagram (Figure N-18) and clear grouping of sites in the three-dimensional ordination plot (Figure N-16).

The corresponding shade plots (Figure N-19 and Figure N-20) both displayed the tolerant taxon, the Blackfly larvae *Simulium* (SIGNAL-SG grade 4) as persistent through time and consistently abundant at the site 0.3 km downstream of the WWTP in both habitats. This taxon was absent on most collection occasions or occurred in much lower numbers at the 3 km downstream site. These shade plots illustrated that higher graded SIGNAL-SG taxa such as the non-biting midge larvae Chironomidae *Parametrioctenemis* and caddisfly Leptoceridae *Triplectides* were more consistently collected from the site 3 km downstream, suggesting recovery in water quality with distance from the WWTP.

The BVSTEP routine was used to find a subset of taxa whose multivariate pattern matched that of the full dataset with 29 taxa (out of 91) identified for the edge habitat (Table N-27) and 20 taxa (out of 58) for the riffle habitat (Table N-28). These subsets of taxa form the main visual patterns in the respective shade plots (Figure N-19 and Figure N-20).

The PERMDISP analysis indicated a non-significant pattern of dispersion (spacing between same site samples) for the edge (Table N-23) and riffle (Table N-24) habitats. These results imply results of ANOSIM tests are focused on community structure differences between sites.

An ANOSIM test was run on the factor 'Site'. The returned ANOSIM R-values were at mid-range levels (Table N-19) and (Table N-20), implying both downstream sites assemblage structures were distinguishable for both habitats.

To further explore the community structure, hypothesis testing was conducted with a PERMANOVA model. This model comprised the fixed factors 'Site' and 'Year'. 'Year' represented samples collected in years between 2004 and 2020 and 'Site' having two levels, 0.3 km downstream and 3 km downstream. A statistically non-significant 'Site x Year' interaction was returned for the edge (Table N-21) and riffle (Table N-22) habitats. These non-significant results allowed us to view the 'Site' and 'Year' results. Statistically significant results were returned for 'Year' and 'Site' factors. The estimates of components of variation indicated 'Site' explained approximately twice the variation than that explained by 'Year' for the edge habitat (Table N-21) and four times the variation than that explained by 'Year' for the riffle habitat (Table N-22).

A second run of ANOSIM based on 'Site-period' groups displayed in ordination plots Figure N-15 and Figure N-16 returned a significant global mid-range R-value of 0.60 for the edge habitat. In the resulting pairwise comparisons, four tests returned R-values at a level ($R = 1.0, 0.875, 0.838$ and



0.782, Table N-25) that can be expected from natural differences between groups from variation in the substratum composition of the habitats between sites. Besley and Chessman (2008) found R-values up to 0.66 for sites on the same near-pristine stream. A lower mid-range global R-value of 0.429 was returned for the riffle habitat with only a single corresponding pairwise test for the riffle habitat returned above an R-value of 0.66 (Table N-26).

These multivariate analysis results suggested community structure alteration from wastewater discharge in the unnamed creek was most evident in macroinvertebrate assemblages within the edge habitat.

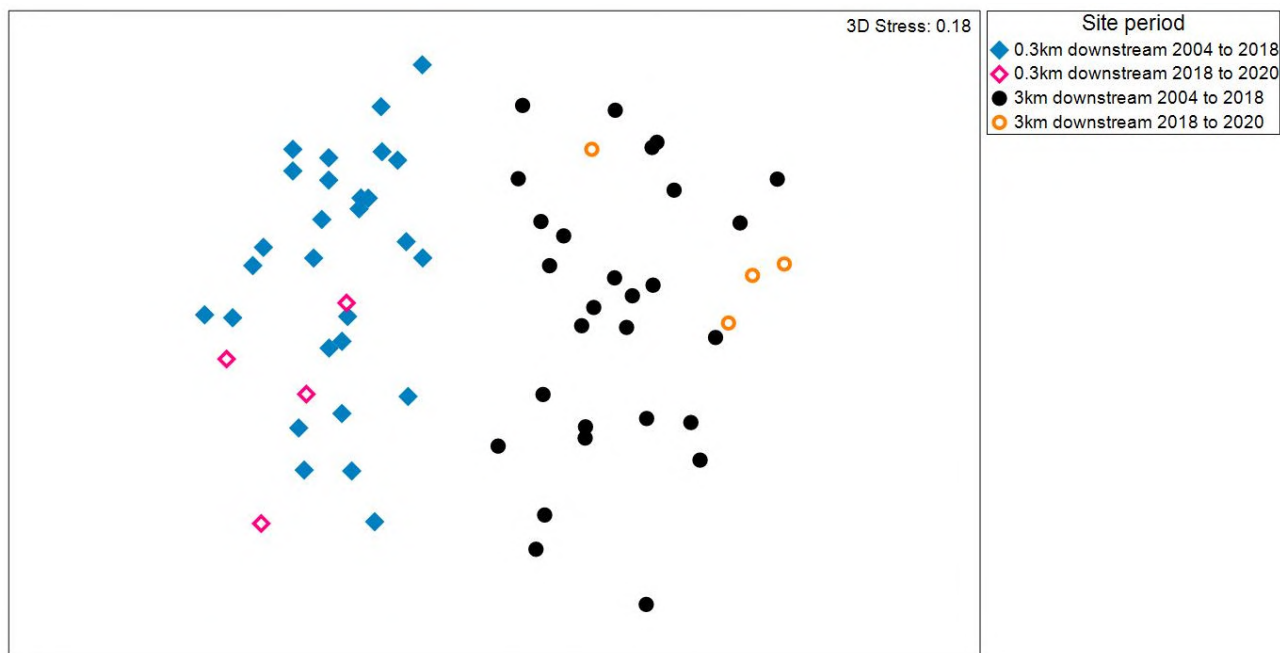


Figure N-15 Dimensions 1 and 3 of three-dimensional ordination plot of freshwater macroinvertebrate edge habitat community structure of both downstream sites of unnamed creek below Winmalee WWTP

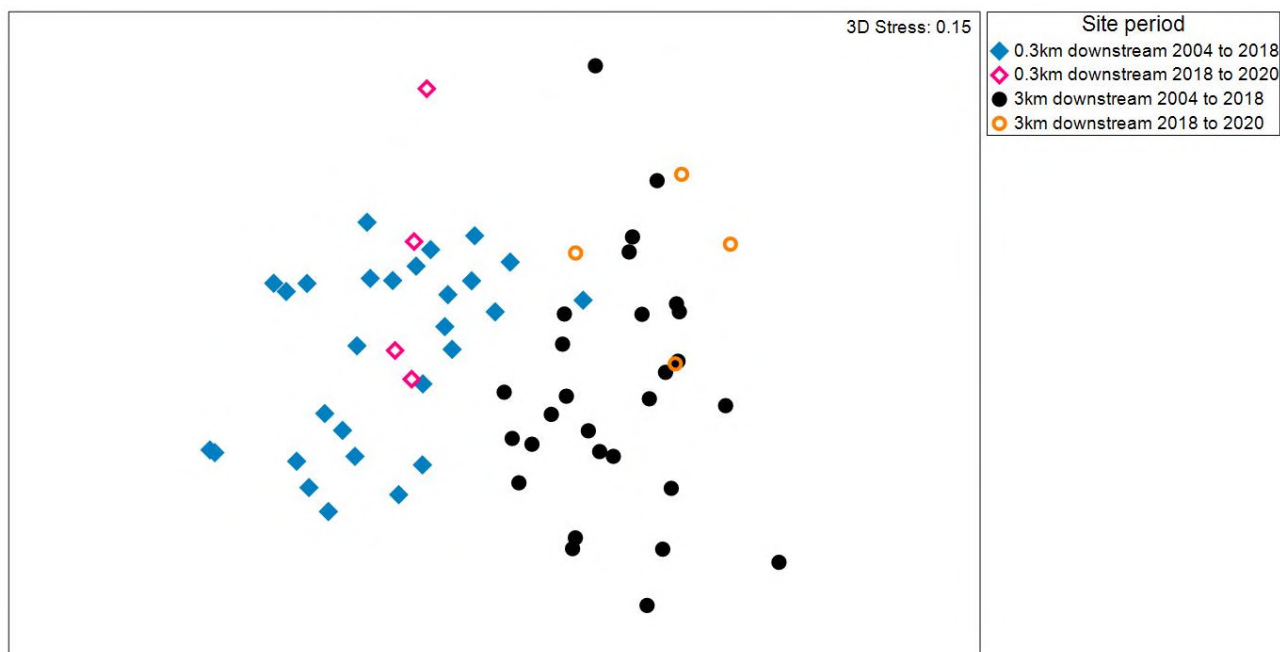


Figure N-16 Dimensions 1 and 2 of three-dimensional ordination plot of freshwater macroinvertebrate riffle habitat community structure of both downstream sites of unnamed creek below Winmalee WWTP

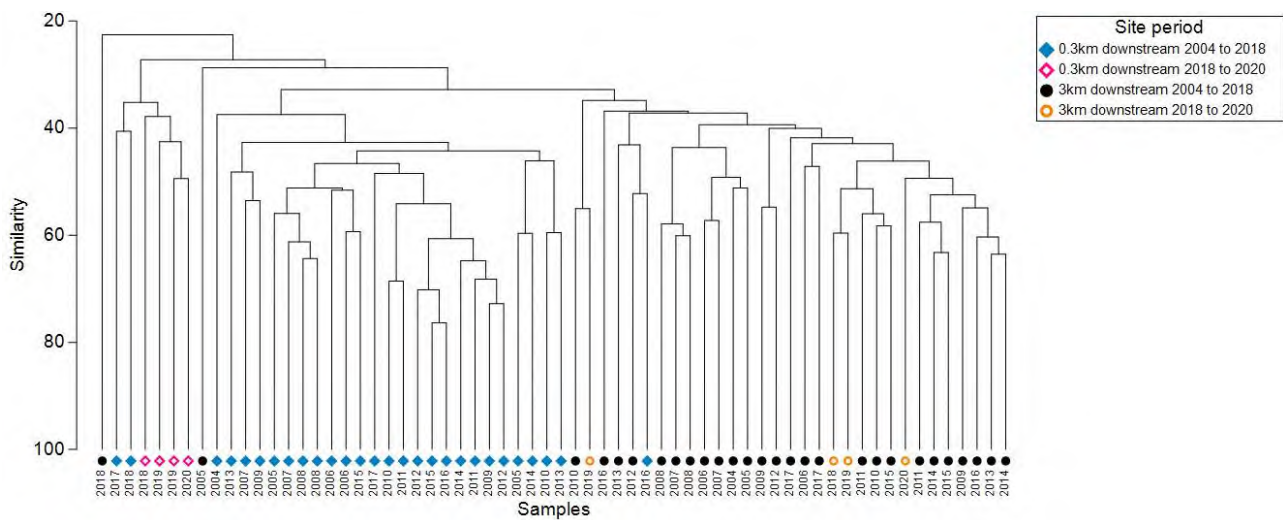


Figure N-17 Tree diagram of freshwater macroinvertebrate edge habitat community structure of both downstream sites of unnamed creek below Winmalee WWTP

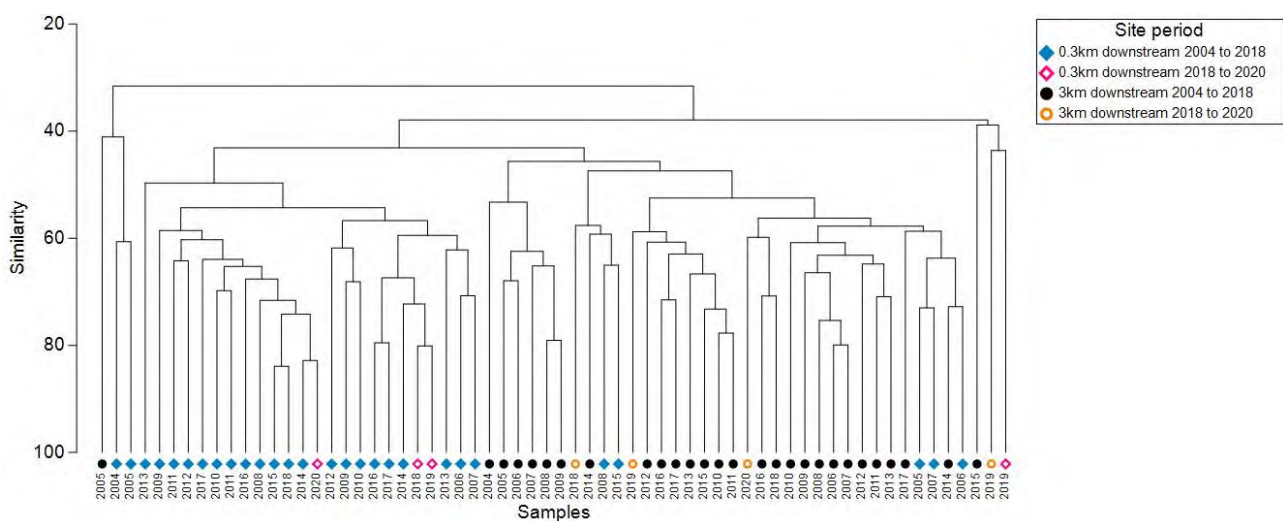


Figure N-18 Tree diagram of freshwater macroinvertebrate riffle habitat community structure of both downstream sites of unnamed creek below Winmalee WWTP

Table N-19 ANOSIM test of 'Site' factor for edge habitat unnamed creek near Winmalee WWTP

Tests for differences between unordered Site groups

Global Test

Sample statistic (R): 0.538

Significance level of sample statistic: 0.01%

Number of permutations: 9999 (Random sample from a large number)

Number of permuted statistics greater than or equal to R: 0

Table N-20 ANOSIM test of 'Site' factor for riffle habitat unnamed creek below Winmalee WWTP

Tests for differences between unordered Site groups

Global Test

Sample statistic (R): 0.49

Significance level of sample statistic: 0.01%

Number of permutations: 9999 (Random sample from a large number)

Number of permuted statistics greater than or equal to R: 0

Table N-21 PERMANOVA test of 'Site' and 'Year' factors for edge habitat unnamed creek below Winmalee WWTP

Sums of squares type: Type III (partial)

Fixed effects sum to zero for mixed terms

Permutation method: Permutation of residuals under a reduced model

Number of permutations: 9999

PERMANOVA table of results

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms
Site	1	20821	20821	14.671	0.0001	9937
Year	16	43702	2731.4	1.9246	0.0001	9749
SitexYear	16	26584	1661.5	1.1707	0.0601	9742
Res	30	42576	1419.2			
Total	63	1.3517E+05				

Estimates of components of variation

Source	Estimate	Sq.root
S(Site)	637.77	25.254
S(Year)	349.19	18.687
S(SitexYear)	128.94	11.355
V(Res)	1419.2	37.672

Table N-22 PERMANOVA test of 'Site' and 'Year' factors for riffle habitat unnamed creek below Winmalee WWTP

Sums of squares type: Type III (partial)

Fixed effects sum to zero for mixed terms

Permutation method: Permutation of residuals under a reduced model

Number of permutations: 9999

PERMANOVA table of results

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms
Site	1	19857	19857	17.595	0.0001	9934
Year	16	26825	1676.6	1.4856	0.0031	9797
SitexYear	16	16217	1013.6	0.89811	0.7454	9811
Res	30	33857	1128.6			
Total	63	96518				

Estimates of components of variation

Source	Estimate	Sq.root
S(Site)	615.63	24.812
S(Year)	145.83	12.076
S(SitexYear)	-61.201	-7.8231
V(Res)	1128.6	33.594

Table N-23 PERMDISP test of 'Site' factor for edge habitat unnamed creek below Winmalee WWTP

DEVIATIONS FROM CENTROID

F: 0.29336 df1: 1 df2: 62

P(perm): 0.6204

MEANS AND STANDARD ERRORS

Group	Size	Average	SE
3km downstream	32	41.868	1.1904
0.3km downstream	32	40.881	1.3777

Table N-24 PERMDISP test of 'Site' factor for riffle habitat unnamed creek below Winmalee WWTP

DEVIATIONS FROM CENTROID

F: 0.45791 df1: 1 df2: 62

P(perm): 0.5305

MEANS AND STANDARD ERRORS

Group	Size	Average	SE
3km downstream	32	34.468	1.2517
0.3km downstream	32	33.163	1.4666

Table N-25 ANOSIM test of 'Site period' samples for edge habitat unnamed creek below Winmalee WWTP

Global Test

Sample statistic (R): 0.6

Significance level of sample statistic: 0.01%

Number of permutations: 9999 (Random sample from a large number)

Number of permuted statistics greater than or equal to R: 0

Pairwise Tests

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
3km downstream 2004 to 2018, 3km downstream 2018 to 2020	0.116	21.3	35960	9999	2133
3km downstream 2004 to 2018, 0.3km downstream 2004 to 2018	0.562	0.01	Very large	9999	0
3km downstream 2004 to 2018, 0.3km downstream 2018 to 2020	0.875	0.01	35960	9999	0
3km downstream 2018 to 2020, 0.3km downstream 2004 to 2018	0.838	0.02	35960	9999	1
3km downstream 2018 to 2020, 0.3km downstream 2018 to 2020	1	2.9	35	35	1
0.3km downstream 2004 to 2018, 0.3km downstream 2018 to 2020	0.782	0.02	35960	9999	1

Table N-26 ANOSIM test of 'Site period' samples for riffle habitat unnamed creek below Winmalee WWTP

Global Test

Sample statistic (R): 0.429

Significance level of sample statistic: 0.01%

Number of permutations: 9999 (Random sample from a large number)

Number of permuted statistics greater than or equal to R: 0

Pairwise Tests

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
Downstream 2004 to 2018, Downstream 2018 to 2020	0.225	7.8	35960	9999	776
Downstream 2004 to 2018, 0.3km downstream 2004 to 2018	0.493	0.01	Very large	9999	0
Downstream 2004 to 2018, 0.3km downstream 2018 to 2020	0.441	0.5	35960	9999	51
Downstream 2018 to 2020, 0.3km downstream 2004 to 2018	0.635	0.05	35960	9999	4
Downstream 2018 to 2020, 0.3km downstream 2018 to 2020	0.771	2.9	35	35	1
0.3km downstream 2004 to 2018, 0.3km downstream 2018 to 2020	-0.083	66.1	35960	9999	6606

Table N-27 Genera subset whose multivariate pattern matches full genera set of the edge habitat unnamed creek below Winmalee WWTP

Subset of 29 (correlation 0.951) genera from edge habitat whose pattern matches that of the full set of 91 genera identified with the same subset found on 22 runs from 50 random start runs. Each run was based on three randomly selected genera. Genera were:

Chironomidae *Chironomus*, Physidae *Physella*, Chironomidae *Cricotopus*, DugesIIDae *Cura*, Glossiphoniidae *Helobdella*, Lumbriculidae *Lumbriculus*, Simuliidae *Simulium*, Argiolestidae *Austroargiolestes*, Chironomidae *Microtendipes*, Chironomidae *Polypedilum*, Chironomidae *Rheocricotopus*, Chironomidae *Rheotanytarsus*, Chironomidae *Thienemanniella*, Hydropsychidae *Cheumatopsyche*, Libellulidae *Nannophlebia*, Scyphacidae *Haloniscus*, Talitridae *Arcitalitrus*, Tateidae *Potamopyrgus*, Atyidae *Paratya*, Elmidae *Notriolus*, Elmidae *Simsonia*, Hydraenidae *Hydraena*, Hydroptilidae *Hellyethira*, Leptoceridae *Notalina*, Micronectidae *Micronecta*, Aeshnidae *Austroaeschna*, Veliidae *Microvelia*, Chironomidae *Tanytarsus*, Leptoceridae *Triplectides*.

Table N-28 Genera subset whose multivariate pattern matches full genera set of the riffle habitat unnamed creek below Winmalee WWTP

Subset of 20 (correlation 0.954) genera from riffle habitat whose pattern matches that of the full set of 58 genera identified with the same subset found on one run from 50 random start runs. Each run was based on three randomly selected genera. Genera were:

Chironomidae *Chironomus*, Chironomidae *Cardiocladius*, Chironomidae *Cricotopus*, DugesIIDae *Cura*, Naididae *Nais*, Simuliidae *Simulium*, Argiolestidae *Austroargiolestes*, Chironomidae *Eukiefferiella*, Chironomidae *Polypedilum*, Chironomidae *Rheocricotopus*, Chironomidae *Rheotanytarsus*, Chironomidae *Thienemanniella*, Hydropsychidae *Cheumatopsyche*, Libellulidae *Nannophlebia*, Tateidae *Potamopyrgus*, Elmidae *Notriolus*, Elmidae *Simsonia*, Hydrobiosidae *Ulmerochorema*, Aeshnidae *Austroaeschna*, Chironomidae *Parametriocnemus*.



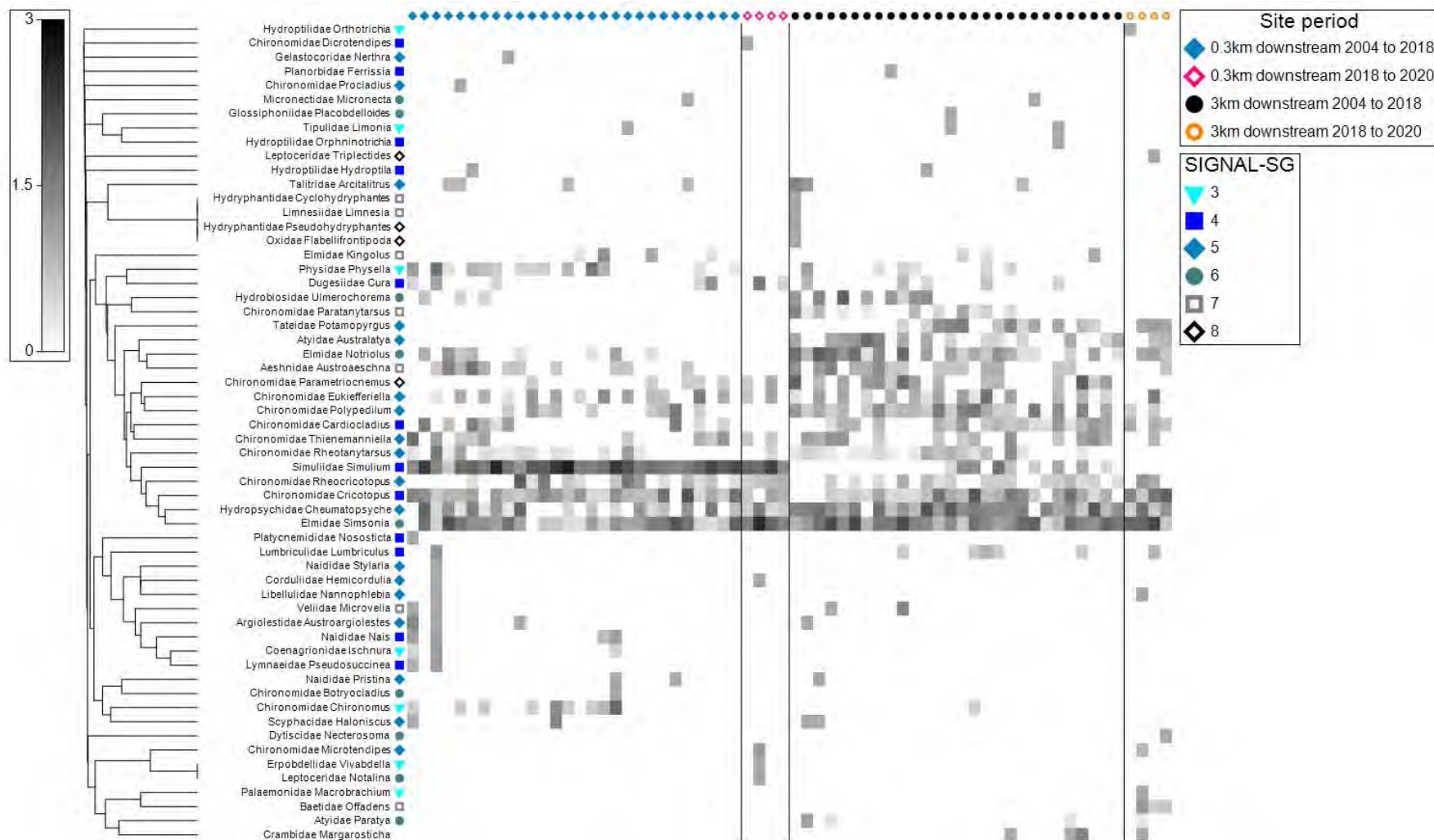


Figure N-20 Shade plot of freshwater macroinvertebrate riffle habitat community structure of both downstream sites of unnamed creek below Winmalee WWTP



Sufficient macrophyte and edge habitat data were collected consistently enough at upstream-downstream sites on the same sampling occasions to allow multivariate analysis for the monitoring period of 1995 to 2020 (less sample collection gaps outlined in Volume 1 Table 3-2). Samples from each habitat were analysed separately.

The Nepean River macrophyte and edge habitat data pattern were visually displayed in a three-dimensional nMDS ordination plots achieve an acceptable level of fit (stress) due to inherent variation. Data points were colour coded by 'Site period' with two periods 1995 to 2018 and 2018 to 2020. There was no clear separation of groups of upstream and downstream samples in either of the ordination plots (Figure N-21 and Figure N-22). Rather a mix of upstream and downstream samples was observed, with most recent samples intermingling with past samples.

The lack of a clear pattern between sites in the ordination plots (Figure N-21 and Figure N-22) was also apparent in the corresponding tree diagrams (Figure N-23 and Figure N-24) and shade plots (Figure N-25 and Figure N-26) suggesting communities between sites were similar. Subsets of taxa defining the multivariate pattern are listed in Table N-37 and Table N-38.

The PERMDISP analysis returned non-significant for both macrophyte (Table N-33) and edge (Table N-34) habitats. This implies results of ANOSIM tests are focused on community structure differences between upstream-downstream sites.

An ANOSIM test was run on the factor 'Site'. The returned ANOSIM R-values were at very low levels close to zero (Table N-29 and Table N-30) implying the assemblage structure of sites were almost indistinguishable.

To further explore community structure, hypothesis testing was conducted with a PERMANOVA model. This model comprised the fixed factors 'Site' and 'Year' with 'Year' representing samples collected in years between 1995 and 2020 and 'Site' having two levels, upstream and downstream. For the macrophyte habitat a statistically non-significant 'Site x Year' interaction was returned (Table N-31). This non-significant result allowed us to view the 'Site' and 'Year' results. Significant results were returned for 'Site' and 'Year' factors. Inspecting estimates of components of variation output indicated that 'Year' explained about seven times the variation than that explained by 'Site' (Table N-31). For the edge habitat, a statistically non-significant 'Site x Year' interaction was returned (Table N-32). Both 'Site' and 'Year' factors resulted in significant results. Inspecting estimates of components of variation output indicated 'Year' explained more than three times the variation than that explained by 'Site' (Table N-32).

A second run of ANOSIM based on 'Site-period' samples displayed in ordination plots (Figure N-21 and Figure N-22) returned a non-significant global R-value for the macrophyte habitat (Table N-35) and for the edge habitat a significant global R-value of 0.104, but this was relatively low (Table N-36). Inspection of pairwise tests for the edge habitat indicated five of the six comparisons were non-significant and the only significant test had a low-range R-value of 0.111 (Table N-36).

These results suggested community structure in the unnamed creek near the WWTP was altered by wastewater discharge from Winmalee WWTP but this impact did not extend as far as the Nepean River.

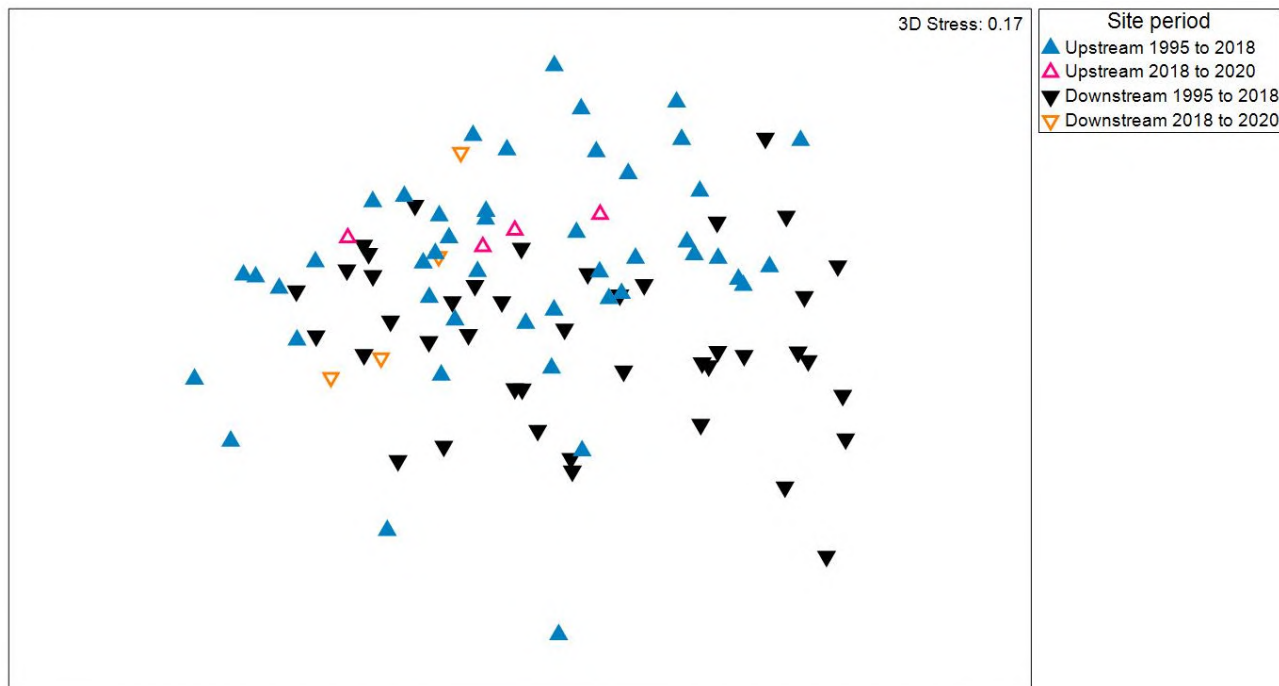


Figure N-21 Dimensions 1 and 3 of three-dimensional nMDS ordination plot of freshwater macroinvertebrate macrophyte habitat community structure of sites upstream-downstream of Nepean River at the confluence of the unnamed creek into which Winmalee WWTP discharges

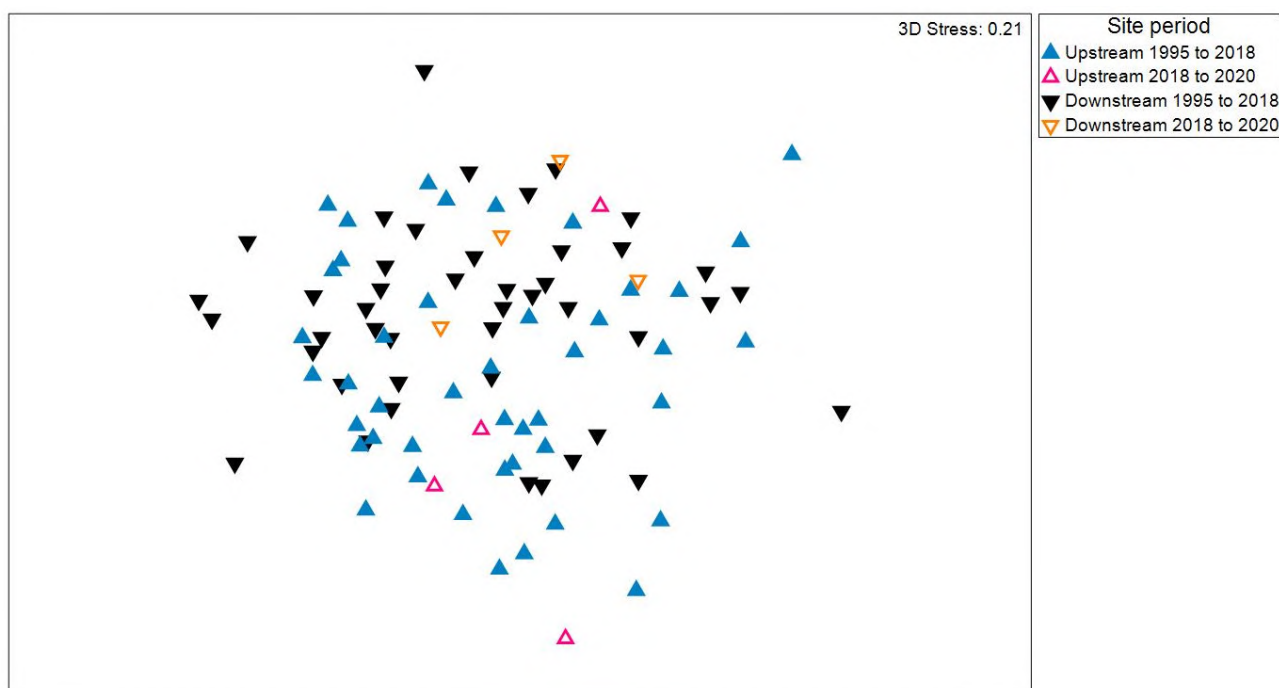


Figure N-22 Dimensions 1 and 3 of three-dimensional ordination plot of freshwater macroinvertebrate edge habitat community structure of sites upstream-downstream of Nepean River at the confluence of the unnamed creek into which Winmalee WWTP discharges

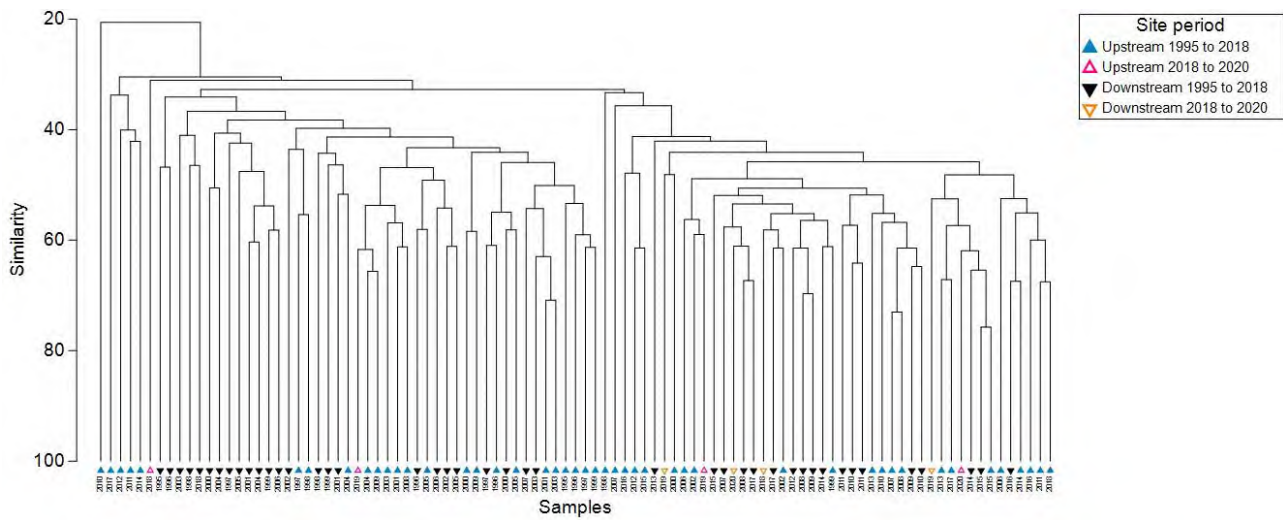


Figure N-23 Tree diagram of freshwater macroinvertebrate macrophyte habitat community structure of sites upstream-downstream of Nepean River at the confluence of the unnamed creek into which Winmalee WWTP discharges

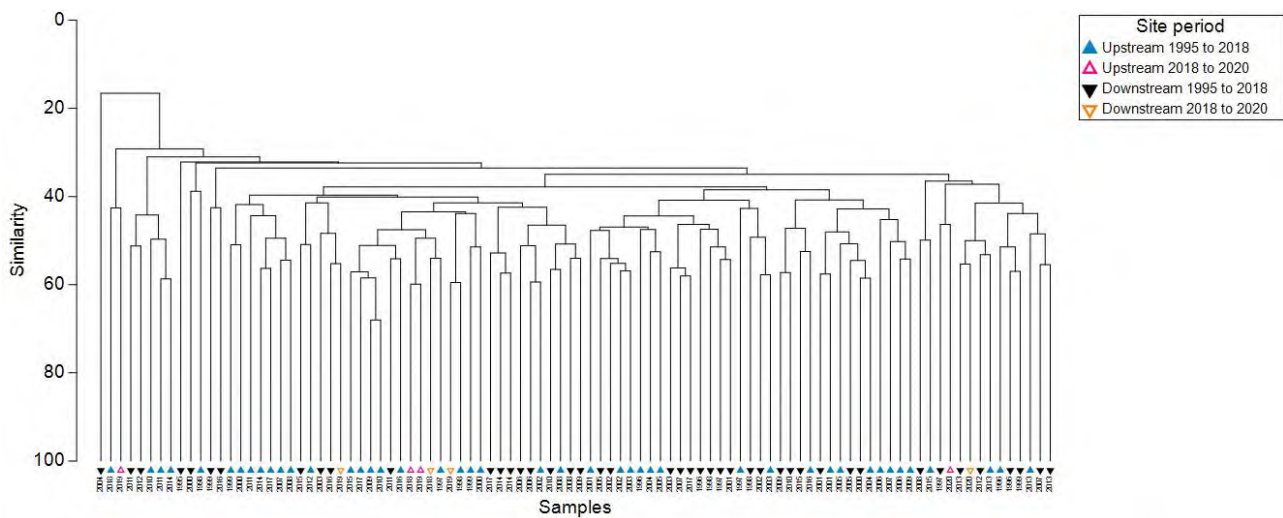


Figure N-24 Tree diagram of freshwater macroinvertebrate edge habitat community structure of sites upstream-downstream of Nepean River at the confluence of the unnamed creek into which Winmalee WWTP discharges



Table N-29 ANOSIM test of 'Site' for macrophyte habitat of upstream-downstream sites of Nepean River at the confluence of the unnamed creek into which Winmalee WWTP discharges

Tests for differences between unordered Site groups

Global Test

Sample statistic (R): 0.035

Significance level of sample statistic: 2.1%

Number of permutations: 9999 (Random sample from a large number)

Number of permuted statistics greater than or equal to R: 210

Table N-30 ANOSIM test of 'Site' for edge habitat Nepean River at the confluence of the unnamed creek into which Winmalee WWTP discharges

Tests for differences between unordered Site groups

Global Test

Sample statistic (R): 0.101

Significance level of sample statistic: 0.01%

Number of permutations: 9999 (Random sample from a large number)

Number of permuted statistics greater than or equal to R: 0

Table N-31 PERMANOVA test of 'Site' and 'Year' factors for macrophyte habitat of upstream-downstream sites of Nepean River at the confluence of the unnamed creek into which Winmalee WWTP discharges

Sums of squares type: Type III (partial)

Fixed effects sum to zero for mixed terms

Permutation method: Permutation of residuals under a reduced model

Number of permutations: 9999

PERMANOVA table of results

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms
Site	1	3834.8	3834.8	2.2594	0.0074	9916
Year	25	74831	2993.3	1.7636	0.0001	9711
SitexYear	25	40407	1616.3	0.95227	0.7067	9700
Res	45	76378	1697.3			
Total	96	1.9655E+05				

Estimates of components of variation

Source	Estimate	Sq.root
S(Site)	46.64	6.8294
S(Year)	351.42	18.746
S(SitexYear)	-43.939	-6.6286
V(Res)	1697.3	41.198

Table N-32 PERMANOVA test of 'Site' and 'Year' factors for edge habitat of upstream-downstream sites of Nepean River at the confluence of the unnamed creek into which Winmalee WWTP discharges

Sums of squares type: Type III (partial)

Fixed effects sum to zero for mixed terms

Permutation method: Permutation of residuals under a reduced model

Number of permutations: 9999

PERMANOVA table of results

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms
Site	1	5642.2	5642.2	3.3819	0.0001	9920
Year	25	71296	2851.9	1.7094	0.0001	9638
SitexYear**	24	43024	1792.6	1.0745	0.1634	9638
Res	45	75077	1668.4			
Total	95	1.9566E+05				

Estimates of components of variation

Source	Estimate	Sq.root
S(Site)	87.425	9.3501
S(Year)	324.51	18.014
S(SitexYear)	66.165	8.1342
V(Res)	1668.4	40.846

Table N-33 PERMDISP test of 'Site' for macrophyte habitat of upstream-downstream sites of Nepean River at the confluence of the unnamed creek into which Winmalee WWTP discharges

DEVIATIONS FROM CENTROID

F: 0.098726 df1: 1 df2: 95

P(perm): 0.762

MEANS AND STANDARD ERRORS

Group	Size	Average	SE
Downstream	47	43.744	0.97847
Upstream	50	44.192	1.0318

Table N-34 PERMDISP test of 'Site' for edge habitat of upstream-downstream sites of Nepean River at the confluence of the unnamed creek into which Winmalee WWTP discharges

DEVIATIONS FROM CENTROID

F: 0.015608 df1: 1 df2: 94

P(perm): 0.9019

MEANS AND STANDARD ERRORS

Group	Size	Average	SE
Downstream	48	44.123	0.83037
Upstream	48	43.982	0.76377

Table N-35 ANOSIM test of 'Site period' for macrophyte habitat of upstream-downstream sites of Nepean River at the confluence of the unnamed creek into which Winmalee WWTP discharges

Tests for differences between unordered Site period groups

Global Test

Sample statistic (R): 0.025

Significance level of sample statistic: 19.8%

Number of permutations: 9999 (Random sample from a large number)

Number of permuted statistics greater than or equal to R: 1977

Pairwise Tests

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
Downstream 1995 to 2018, Downstream 2018 to 2020	-0.039	60	178365	9999	5997
Downstream 1995 to 2018, Upstream 1995 to 2018	0.037	2.3	Very large	9999	229
Downstream 1995 to 2018, Upstream 2018 to 2020	0.105	19.9	178365	9999	1985
Downstream 2018 to 2020, Upstream 1995 to 2018	-0.107	76.9	230300	9999	7687
Downstream 2018 to 2020, Upstream 2018 to 2020	0.302	8.6	35	35	3
Upstream 1995 to 2018, Upstream 2018 to 2020	-0.006	48.2	230300	9999	4822

Table N-36 ANOSIM test of 'Site period' for edge habitat of upstream-downstream sites of Nepean River at the confluence of the unnamed creek into which Winmalee WWTP discharges

Tests for differences between unordered Site period groups

Global Test

Sample statistic (R): 0.104

Significance level of sample statistic: 0.04%

Number of permutations: 9999 (Random sample from a large number)

Number of permuted statistics greater than or equal to R: 3

Pairwise Tests

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
Downstream 1995 to 2018, Downstream 2018 to 2020	-0.073	68.8	194580	9999	6875
Downstream 1995 to 2018, Upstream 1995 to 2018	0.111	0.01	Very large	9999	0
Downstream 1995 to 2018, Upstream 2018 to 2020	0.206	8.3	194580	9999	832
Downstream 2018 to 2020, Upstream 1995 to 2018	0.014	42.7	194580	9999	4264
Downstream 2018 to 2020, Upstream 2018 to 2020	0.26	17.1	35	35	6
Upstream 1995 to 2018, Upstream 2018 to 2020	0.183	9.8	194580	9999	979



Table N-37 Genera subset whose multivariate pattern matches full genera set of the macrophyte habitat of upstream-downstream sites of Nepean River at the confluence of the unnamed creek into which Winmalee WWTP discharges

Subset of 34 (correlation 0.950) genera from macrophyte habitat whose pattern matches that of the full set of 129 genera identified with the same subset found on two runs from 50 random start runs. Each run was based on three randomly selected genera. Genera were:

Coenagrionidae *Ischnura*, Physidae *Physella*, Chironomidae *Cricotopus*, Chironomidae *Dicrotendipes*, Corbiculidae *Corbicula*, DugesIIDae *Cura*, Lymnaeidae *Pseudosuccinea*, Planorbidae *Ferrissia*, Simuliidae *Simulium*, Chironomidae *Cladotanytarsus*, Chironomidae *Microtendipes*, Chironomidae *Polypedilum*, Chironomidae *Rheotanytarsus*, Chironomidae *Thienemanniella*, Coenagrionidae *Pseudagrion*, Corduliidae *Hemicordulia*, Hebridae *Merragata*, Hydrophilidae *Helochaeres*, Hydropsychidae *Cheumatopsyche*, Libellulidae *Diplacodes*, Libellulidae *Nannophlebia*, Limnesiidae *Physolimnesia*, Atyidae *Paratya*, Baetidae *Cloeon*, Caenidae *Tasmanocoenis*, Ceratopogonidae *Bezzia*, Ecnomidae *Ecnomus*, Hydroptilidae *Hellyethira*, Leptoceridae *Notalina*, Baetidae *Offadens*, Hydrodromidae *Hydrodroma*, Leptoceridae *Oecetis*, Veliidae *Microvelia*, Chironomidae *Tanytarsus*.

Table N-38 Genera subset whose multivariate pattern matches full genera set of the edge habitat of upstream-downstream sites of Nepean River at the confluence of the unnamed creek into which Winmalee WWTP discharges

Subset of 51 (correlation 0.951) genera from edge habitat whose pattern matches that of the full set of 146 genera identified with the same subset found on one run from 50 random start runs. Each run was based on three randomly selected genera. Genera were:

Chironomidae *Chironomus*, Coenagrionidae *Ischnura*, Physidae *Physella*, Chironomidae *Cricotopus*, Chironomidae *Cryptochironomus*, Chironomidae *Dicrotendipes*, Coenagrionidae *Austroagrion*, Corbiculidae *Corbicula*, DugesIIDae *Cura*, Glossiphoniidae *Helobdella*, Lumbriculidae *Lumbriculus*, Lymnaeidae *Pseudosuccinea*, Naucoridae *Naucoris*, Planorbidae *Gyraulus*, Platycnemididae *Nososticta*, Simuliidae *Simulium*, Chironomidae *Cladotanytarsus*, Chironomidae *Microtendipes*, Chironomidae *Polypedilum*, Chironomidae *Procladius*, Chironomidae *Rheocricotopus*, Chironomidae *Rheotanytarsus*, Coenagrionidae *Pseudagrion*, Hydrophilidae *Helochaeres*, Hydropsychidae *Cheumatopsyche*, Libellulidae *Diplacodes*, Libellulidae *Nannophlebia*, Limnesiidae *Physolimnesia*, Mesoveliidae *Mesovelia*, Atyidae *Paratya*, Baetidae *Cloeon*, Caenidae *Tasmanocoenis*, Ceratopogonidae *Bezzia*, Ecnomidae *Ecnomus*, Gomphidae *Austrogomphus*, Hydroptilidae *Hellyethira*, Leptoceridae *Notalina*, Libellulidae *Orthetrum*, Micronectidae *Micronecta*, Baetidae *Offadens*, Chironomidae *Corynoneura*, Hydrodromidae *Hydrodroma*, Hydrophilidae *Berosus*, Leptoceridae *Oecetis*, Unionicolidae *Recifella*, Veliidae *Microvelia*, Calamoceratidae *Anisocentropus*, Chironomidae *Ablabesmyia*, Chironomidae *Tanytarsus*, Hygrobatidae *Coaustraliobates*, Leptoceridae *Triplectides*.



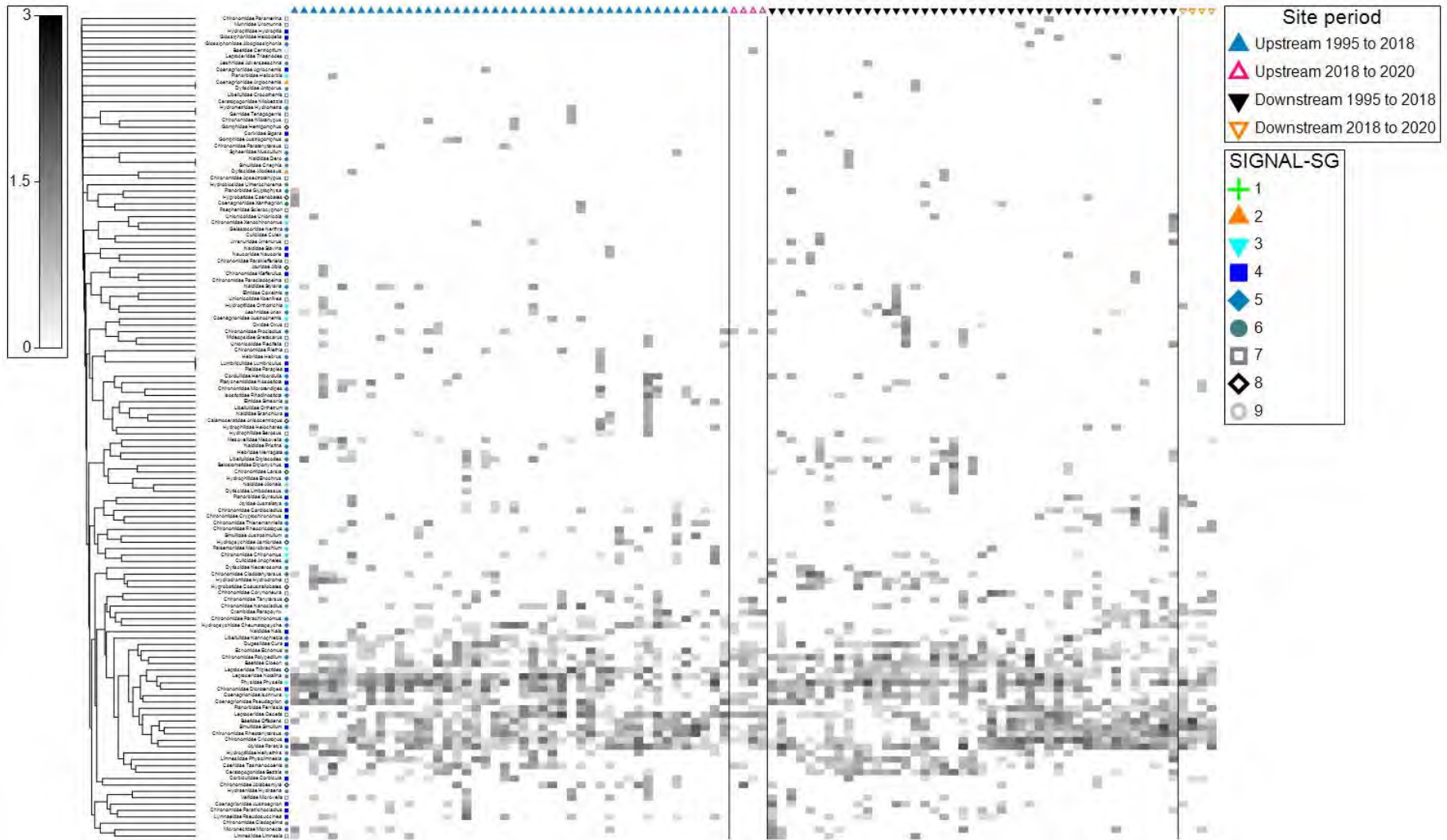


Figure N-25 Shade plot of freshwater macroinvertebrate macrophyte habitat community structure of upstream-downstream sites of Nepean River at the confluence of the unnamed creek into which Winmalee WWTP discharges



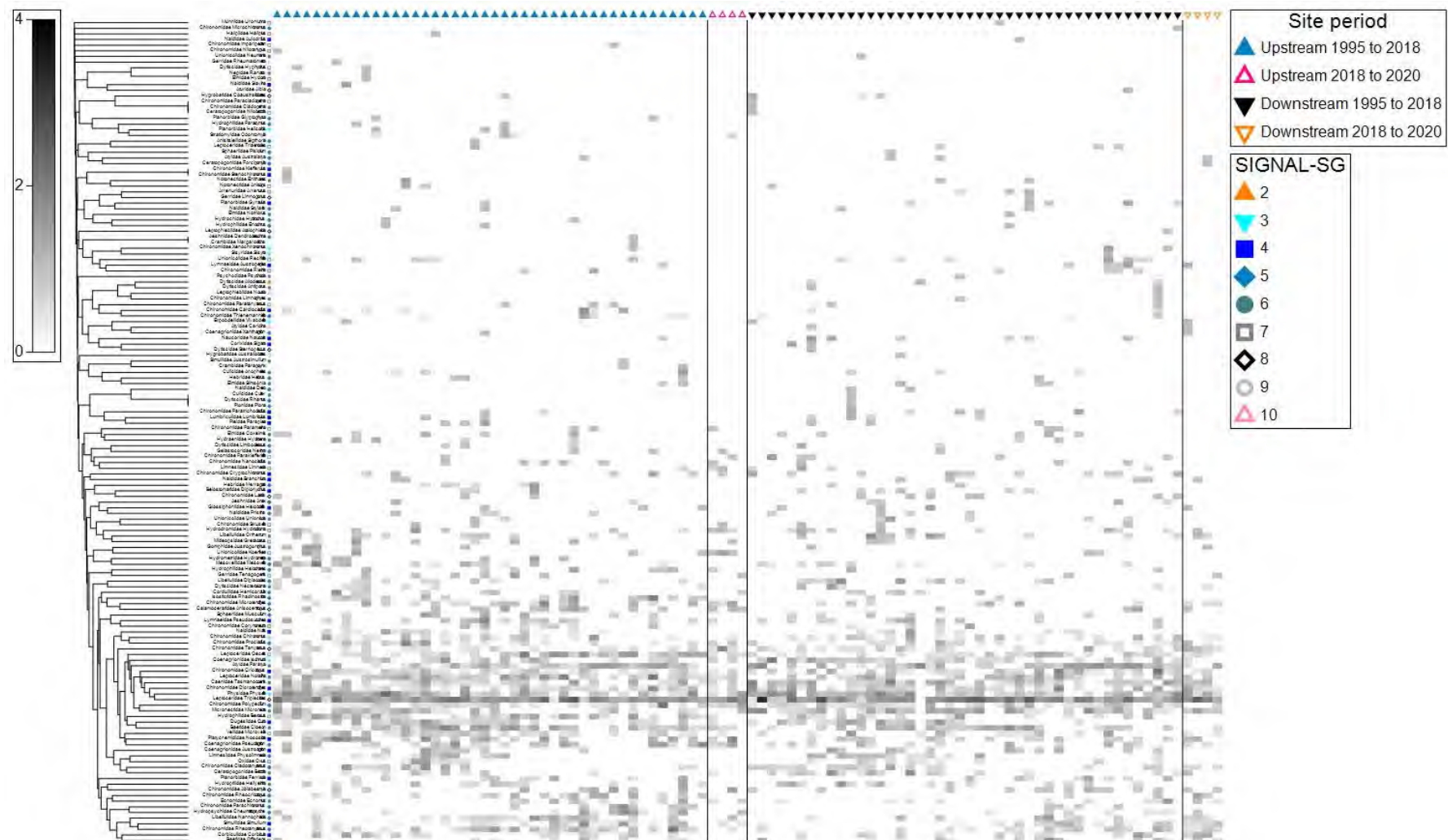


Figure N-26 Shade plot of freshwater macroinvertebrate edge habitat community structure of upstream-downstream sites of Nepean River at the confluence of the unnamed creek into which Winmalee WWTP discharges

Stream health near North Richmond WWTP

The SIGNAL-SG plots provided assessments of stream health for both Redbank Creek near North Richmond WWTP and in the Hawkesbury River upstream-downstream of the confluence with Redbank Creek. These plots were based on macroinvertebrate identification and counting results expressed as SIGNAL-SG scores and allows a visual comparison of data collected from 2019–20 against that collected between 2004 to 2019 for Redbank Creek and 1995 to 2019 for the Hawkesbury River. These visual comparisons suggest that the wastewater discharges from the North Richmond WWTP did not have a measurable negative impact on stream health of the Hawkesbury River over 1995 to 2020 (Figure N-27).

A comparison of the upstream-downstream SIGNAL-SG scores for 2019-20 samples under t-tests returned non-significant outcomes for both the Hawkesbury River and Redbank Creek (Table N-39 and Table N-40) and confirmed the visual trend for 2019-20.

As no measurable impact on downstream stream health was detected, no further data analysis was undertaken.

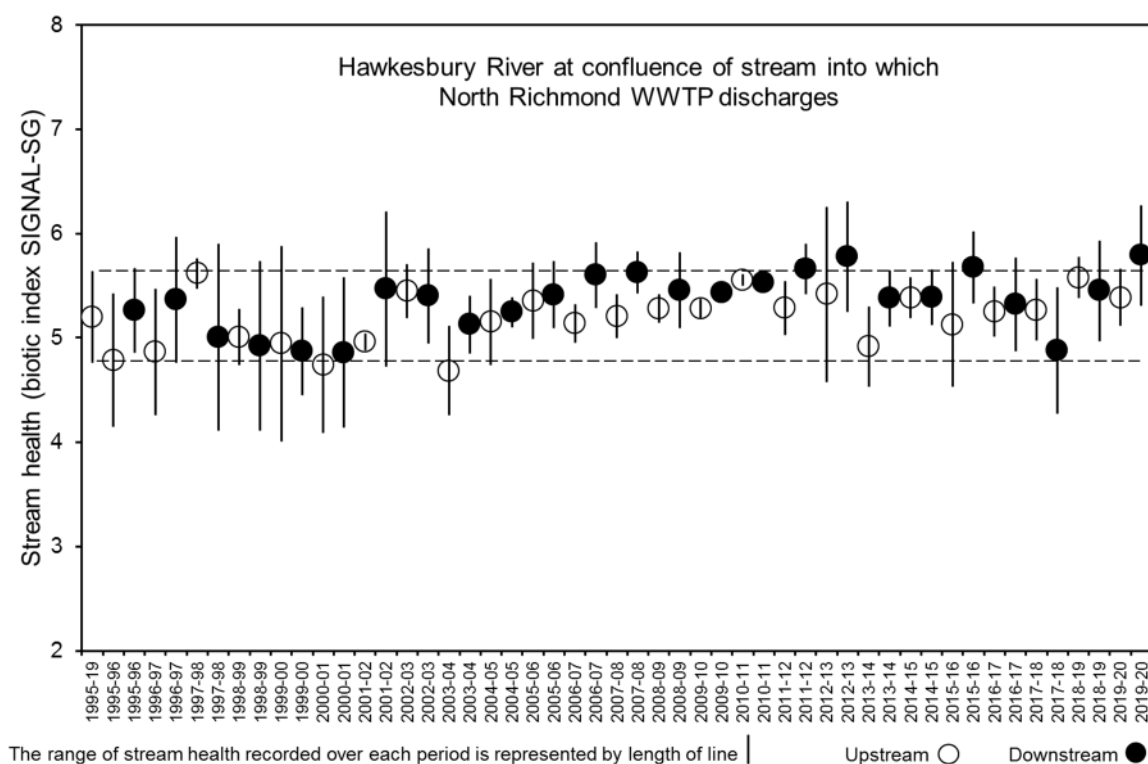


Figure N-27 Stream health of Hawkesbury River upstream-downstream of the confluence of Redbank Creek near North Richmond WWTP

Table N-39 t-test of upstream-downstream SIGNAL-SG scores of 2019-20 samples from the Hawkesbury River near North Richmond WWTP

Method	Variances	DF	t Value	Pr > t
Pooled	Equal	10	1.77	0.1074

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	5	5	3.12	0.2371

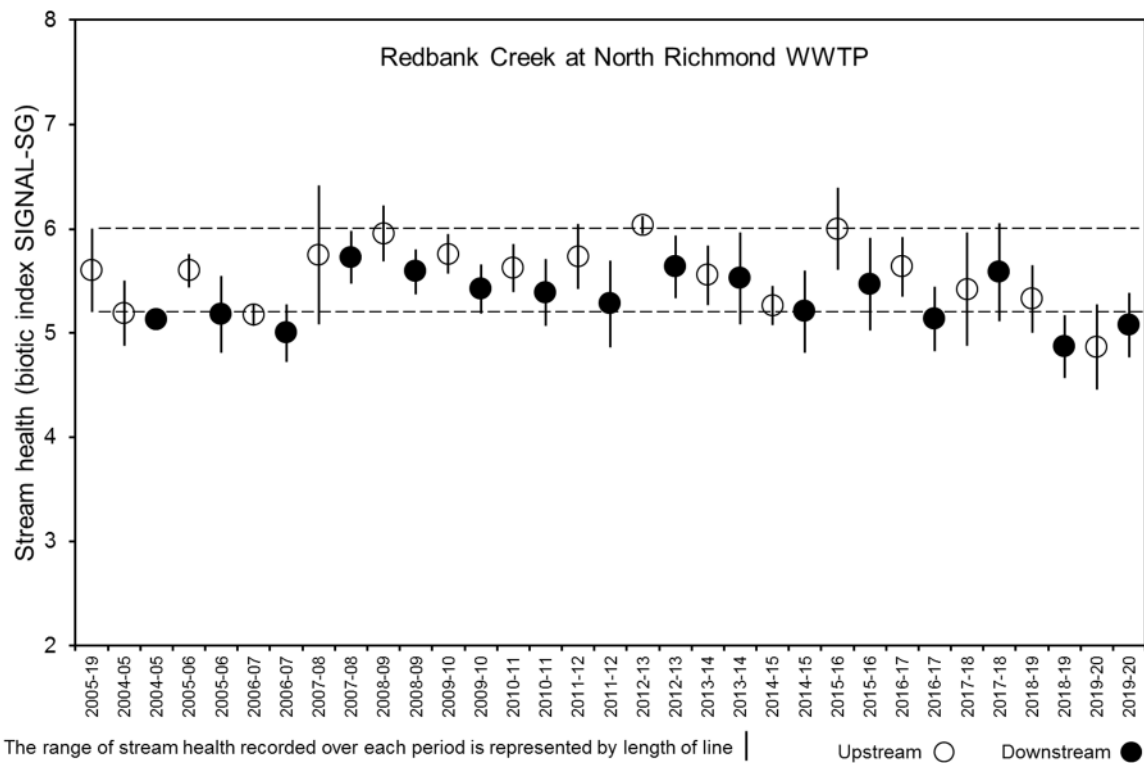


Figure N-28 Stream health of Redbank Creek near North Richmond WWTP

Table N-40 t-test of upstream-downstream SIGNAL-SG scores of 2019-20 samples from Redbank Creek near North Richmond WWTP

Method	Variances	DF	t Value	Pr > t
Pooled	Equal	10	1.00	0.3422

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	5	5	1.77	0.5465

Stream health near St Mary's WWTP

The SIGNAL-SG plot for South Creek provided an assessment of stream health. This plot was based on macroinvertebrate identification and counting results expressed as SIGNAL-SG scores and allows a visual comparison of data collected from 2019–20 against that collected between 1995 and 2019. This comparison suggests downstream stream health was maintained at a level comparable to that of the upstream site indicating wastewater discharge from St Mary's WWTP did not have a measurable impact on stream health during 2019-20 (Figure N-29). When viewing historical aerial maps on Nearmap, it is noted there was a reduction in land clearing activities immediately north of the upstream site in 2017-18 to 2019-20. This may be contributing to the overall improved stream health.

A comparison of the upstream-downstream SIGNAL-SG scores for 2019-20 samples under a t-test returned a non-significant test outcome (Table N-41) and confirmed the visual trend of the SIGNAL-SG plot.

As no measurable negative impact on downstream stream health was detected, no further data analysis was undertaken.

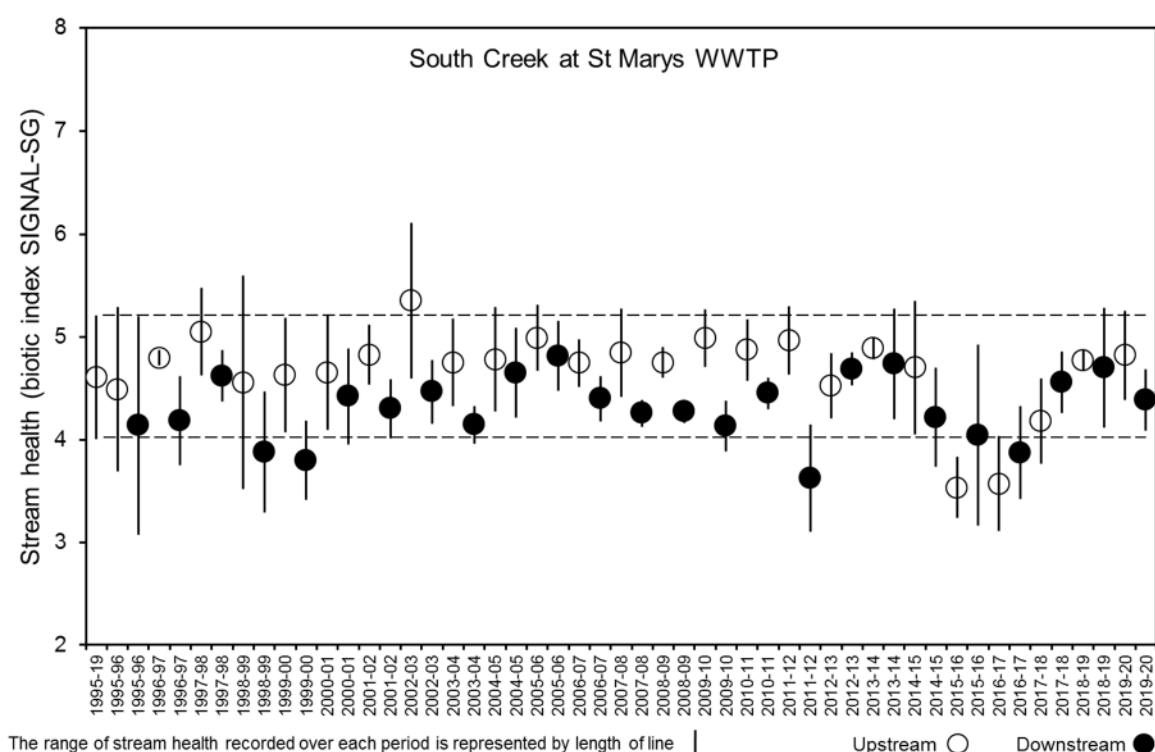


Figure N-29 Stream health of South Creek near St Mary's WWTP

Table N-41 t-test of upstream-downstream SIGNAL-SG scores of 2019-20 samples from South Creek near St Mary's WWTP

Method	Variances	DF	t Value	Pr > t
Pooled	Equal	10	-2.03	0.0695

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	5	5	2.11	0.4317

Stream health near Quakers Hill WWTP

The SIGNAL-SG plot for Breakfast Creek provided an assessment of stream health. This plot was based on macroinvertebrate identification and counting results expressed as SIGNAL-SG scores and allows a visual comparison of data collected from 2019–20 against that collected between 1995 and 2019. This comparison suggests downstream stream health was maintained at a level comparable to that of the upstream site indicating wastewater discharge from Quakers Hill WWTP did not have a measurable impact on stream health during 2019-20 (Figure N-30).

A comparison of the upstream-downstream SIGNAL-SG scores for 2019-20 samples under a t-test returned a non-significant test outcome (Table N-42) and confirmed the visual trend of the SIGNAL-SG plot.

As no measurable impact on downstream stream health was detected, no further data analysis was undertaken.

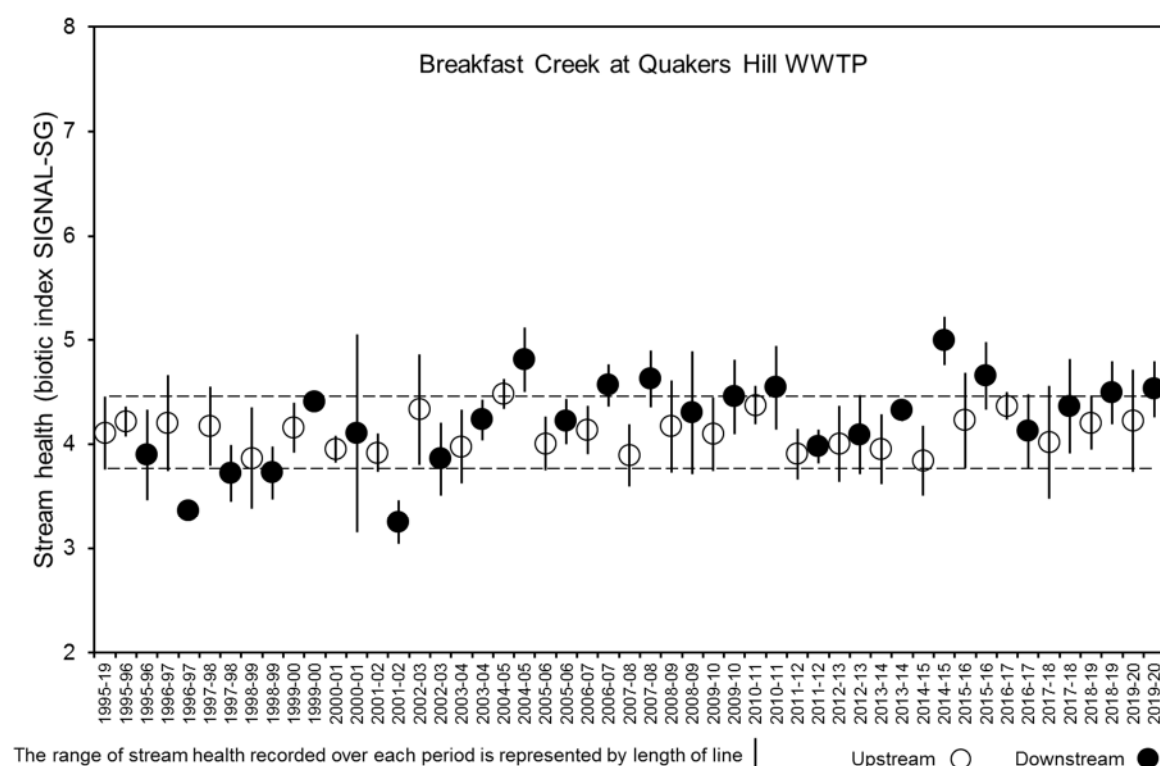


Figure N-30 Stream health of Breakfast Creek near Quakers Hill WWTP

Table N-42 t-test of upstream-downstream SIGNAL-SG scores of 2019-20 samples from Breakfast Creek near Quakers Hill WWTP

Method	Variances	DF	t Value	Pr > t
Pooled	Equal	10	1.33	0.2118

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	5	5	3.33	0.2125

Stream health near Riverstone WWTP

The SIGNAL-SG plot for Eastern Creek provided an assessment of stream health. This plot was based on macroinvertebrate identification and counting results expressed as SIGNAL-SG scores and allows a visual comparison of data collected from 2019–20 against that collected between 1995 and 2019. This comparison suggests downstream stream health was maintained at a level comparable to that of the upstream site indicating wastewater discharge from Riverstone WWTP did not have a measurable impact on stream health during 2019-20 (Figure N-31).

A comparison of the upstream-downstream SIGNAL-SG scores for 2019-20 samples under a t-test returned a non-significant test outcome (Table N-43) and confirmed the visual trend.

As no measurable negative impact on downstream stream health was detected, no further data analysis was undertaken.

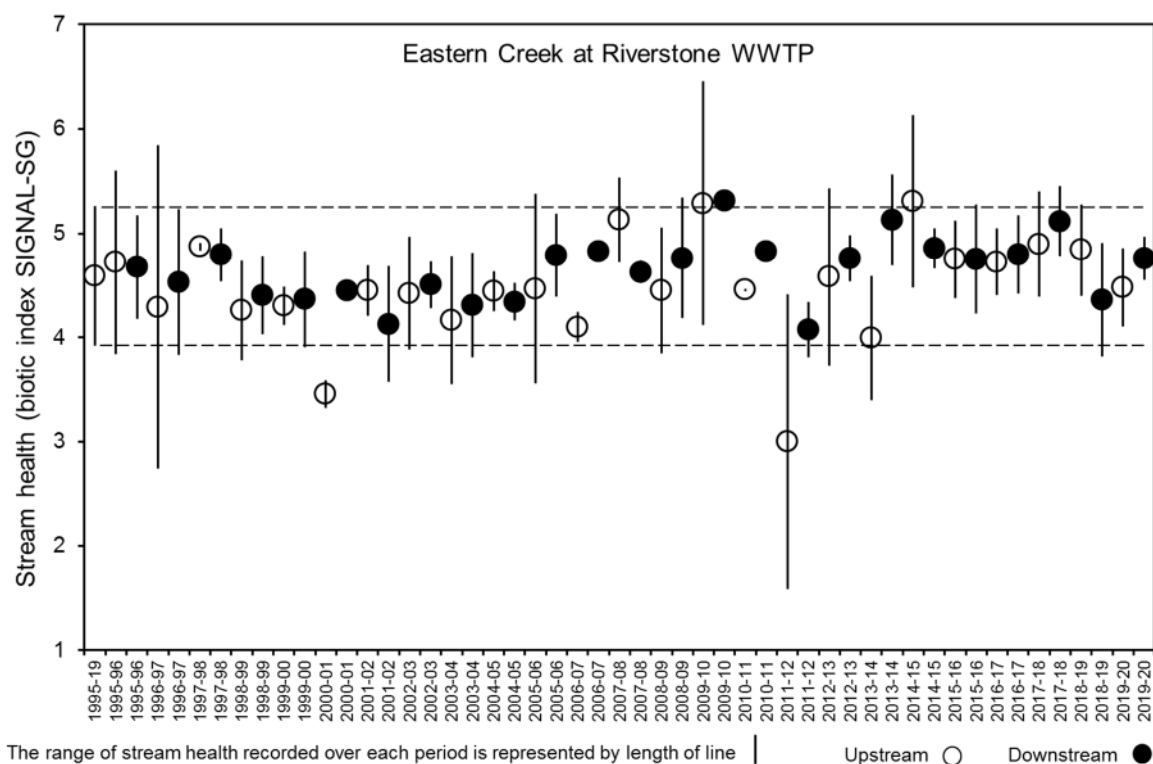


Figure N-31 Stream health of Eastern Creek near Riverstone WWTP

Table N-43 t-test of upstream-downstream SIGNAL-SG scores of 2019-20 samples from Eastern Creek near Riverstone WWTP

Method	Variances	DF	t Value	Pr > t
Pooled	Equal	14	1.84	0.0878

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	7	7	3.20	0.1476

Stream health near Castle Hill WWTP

The SIGNAL-SG plot for Cattai Creek provided an assessment of stream health. This plot was based on macroinvertebrate identification and counting results expressed as SIGNAL-SG scores and allows a visual comparison of data collected from 2019–20 against that collected between 1995 and 2019. This comparison suggests downstream stream health was maintained at a level comparable to that of the upstream site indicating wastewater discharge from Castle Hill WWTP did not have a measurable impact on stream health during 2019-20 (Figure N-32).

A comparison of the upstream-downstream SIGNAL-SG scores for 2019-20 samples under a t-test returned a non-significant test outcome (Table N-44) and confirmed the visual trend.

As no measurable impact on downstream stream health was detected, no further data analysis was undertaken.

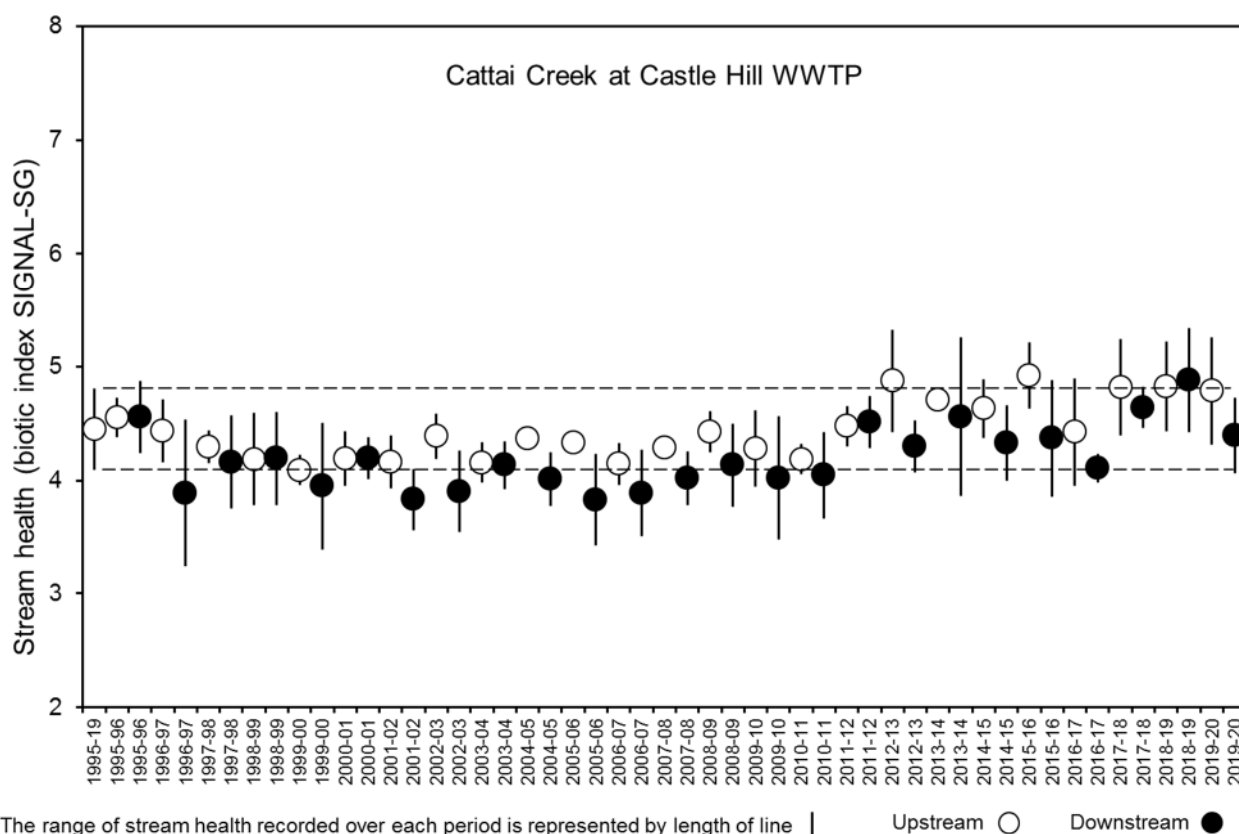


Figure N-32 Stream health of Cattai Creek near Castle Hill WWTP

Table N-44 t-test of upstream-downstream SIGNAL-SG scores of 2019-20 samples from Cattai Creek near Castle Hill WWTP

Method	Variances	DF	t Value	Pr > t
Pooled	Equal	10	-1.67	0.1267

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	5	5	2.01	0.4627

Stream health near Rouse Hill WWTP

The SIGNAL-SG plot for Second Ponds Creek provided an assessment of stream health. This plot was based on macroinvertebrate identification and counting results expressed as SIGNAL-SG scores and allows a visual comparison of data collected from 2019–20 against that collected between 1995 and 2019. This comparison suggests downstream stream health was maintained at a level comparable to that of the upstream site indicating wastewater discharge from Rouse Hill WWTP did not have a measurable impact on stream health during 2019-20 (Figure N-33).

A comparison of the upstream-downstream SIGNAL-SG scores for 2019-20 samples under a t-test returned a non-significant test outcome (Table N-45) and confirmed the visual trend.

As no measurable negative impact on downstream stream health was detected, no further data analysis was undertaken.

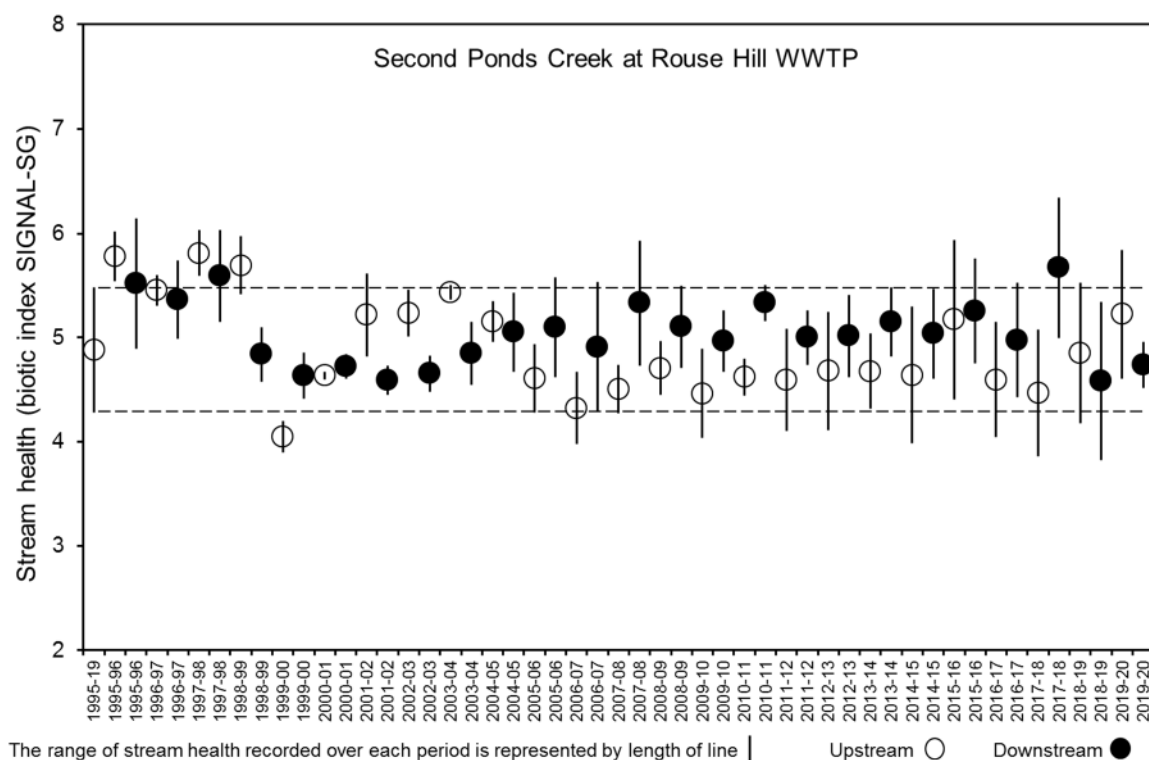


Figure N-33 Stream health of Second Ponds Creek near Rouse Hill WWTP

Table N-45 t-test of upstream-downstream SIGNAL-SG scores of 2019-20 samples from Second Ponds Creek near Rouse Hill WWTP

Method	Variances	DF	t Value	Pr > t
Satterthwaite	Unequal	6.292	-1.81	0.1174

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	5	5	7.61	0.0439

Stream health near Hornsby Heights WWTP

The SIGNAL-SG plot for Calna Creek provided an assessment of stream health. This plot was based on macroinvertebrate identification and counting results expressed as SIGNAL-SG scores and allows a visual comparison of data collected from 2019–20 against that collected between 1996 and 2019. This comparison suggests downstream stream health has not been maintained at a level comparable to that of the upstream site, indicating wastewater discharge from the Hornsby Heights WWTP did have a measurable persistent impact on stream health during over the last nine financial years (Figure N-34).

A comparison of the upstream-downstream SIGNAL-SG scores for 2019-20 samples under a t-test returned a significant test outcome (Table N-46).

As a measurable negative impact on downstream stream health was detected, further analysis of the macroinvertebrate community data was undertaken to explore for trends not revealed in the SIGNAL-SG analysis.

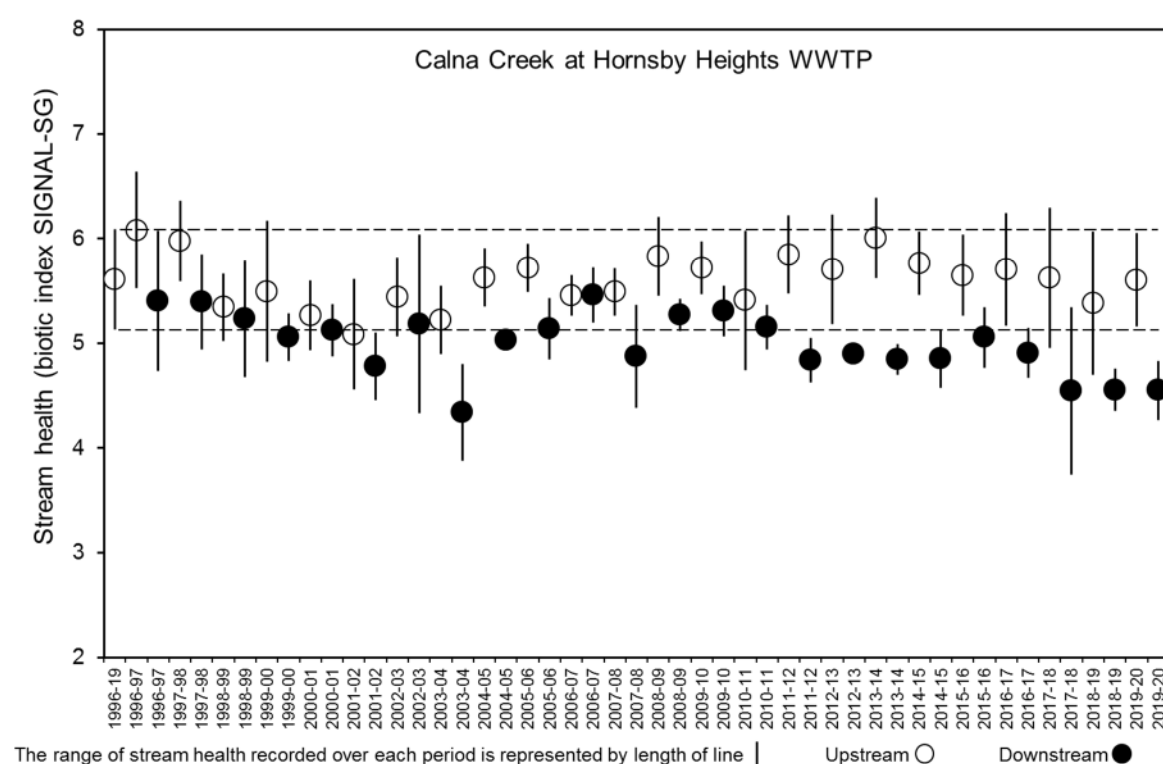


Figure N-34 Stream health of Calna Creek near Hornsby Heights WWTP

Table N-46 t-test of upstream-downstream SIGNAL-SG scores of 2019-20 samples from Calna Creek near Hornsby Heights WWTP

Method	Variances	DF	t Value	Pr > t
Pooled	+Equal	10	-4.93	0.0006

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	5	5	2.50	0.3378



Both edge and riffle habitats were collected consistently enough at upstream-downstream sites on the same sampling occasions to allow a multivariate analysis for the monitoring period of 1996 to 2020. Each habitat (edge and riffle) was analysed separately with comparisons assessed with upstream-downstream sites.

In the three-dimensional nMDS ordination plot of the Calna Creek edge habitat, a relatively interspersed pattern of upstream and downstream samples were observed (Figure N-35). This pattern was confirmed in the corresponding tree diagram from cluster analysis as the first division did not separate a group of upstream samples from another group of downstream samples (Figure N-37). The riffle habitat pattern displayed less overlap of upstream-downstream samples in the Calna Creek ordination plot (Figure N-36) and tree diagram (Figure N-38) compared to the edge habitat.

The PERMDISP analysis indicated a similar pattern of dispersion (spacing between same samples) for the upstream and downstream sites of the riffle habitat (Table N-52). This suggests the variability in taxonomic composition of samples collected over time was similar for upstream and downstream riffle sites through the period 1995 to 2020. As such, the subsequent riffle habitat results of ANOSIM tests were focused on community structure differences between sites. In contrast, significant dispersion was shown for the edge habitat samples (Table N-51). This outcome suggests subsequent edge habitat results of ANOSIM tests are describing both the variability in taxonomic composition of samples over time as well as community composition variability between the upstream and downstream sites.

An ANOSIM test was run on the factor 'Site'. The returned R-values were at a low-range level for edge (Table N-47) and at a mid-range level for riffle (Table N-48). These R-value results suggest site specific assemblages were more distinguishable for the riffle habitat and less distinguishable for the edge habitat. This pattern is reinforced by the shade plots that show a clear difference in sites within the riffle habitat (Figure N-40) and a less distinct pattern within the edge habitat (Figure N-39). These shade plots also show the riffle habitat has a smaller set of taxa (105) compared with the more diverse edge habitat (139 taxa). The BVSTEP routine was used to find a subset of taxa whose multivariate pattern matched that of the full dataset with 30 taxa identified for the riffle habitat (Table N-56) and 36 taxa for the edge habitat (Table N-55). These subsets of taxa reflect those taxa which formed the main visual patterns in the respective shade plots.

To further explore community structure, hypothesis testing was conducted with a PERMANOVA model. This model comprised the fixed factors 'Site' and 'Year' with 'Year' representing samples collected between 1996 and 2020 and 'Site' having two levels, upstream and downstream. A statistically significant 'Site x Year' interaction was returned for both the edge and the riffle habitats (Table N-49 and Table N-50) suggesting a change through time at least at one site.

A second run of ANOSIM based on 'Site-Period' groups in the 3D ordination plots (Figure N-35 and Figure N-36) returned a significant global low-range R-value (0.299) for the edge habitat. Under subsequent upstream-downstream pairwise comparisons, two tests returned an R-value at a level ($R = 0.948$ and 0.851) (Table N-53) that were not expected from natural differences between groups from variation in the substratum composition of the habitats between sites. Besley and Chessman (2008) found R-values up to 0.66 for sites on the same near-pristine stream. A mid-range global R-value (0.579) was returned for the riffle habitat and two of the upstream and downstream pairwise comparisons returned R-values (0.936 and 0.823) (Table N-54) that were at a level that implied more than natural substratum differences between sites.

In summary, the SIGNAL-SG control chart plot showed clear differences between the upstream-downstream sites consistently over the last nine financial years. Variability in the range of stream health levels were also evident for upstream-downstream sites in this SIGNAL-SG control chart. This variability and difference in assemblage structure suggested by SIGNAL-SG results was also evident in multivariate analysis. Both SIGNAL-SG and multivariate results suggest downstream community structure in Calna Creek has been consistently altered by wastewater discharge from the Hornsby Heights WWTP through the 2011 to 2020 monitoring period.

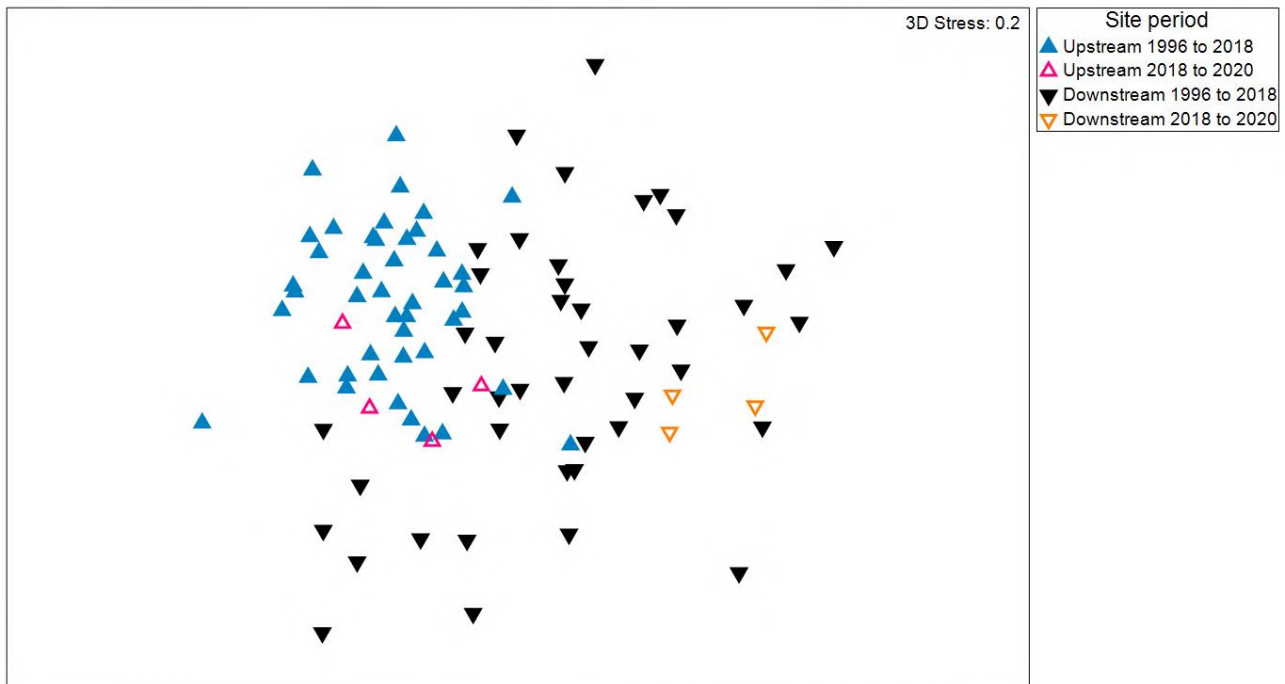


Figure N-35 Dimensions 1 and 3 of three-dimensional ordination plot of freshwater macroinvertebrate edge habitat community structure of upstream-downstream sites of Calna Creek near Hornsby Heights WWTP

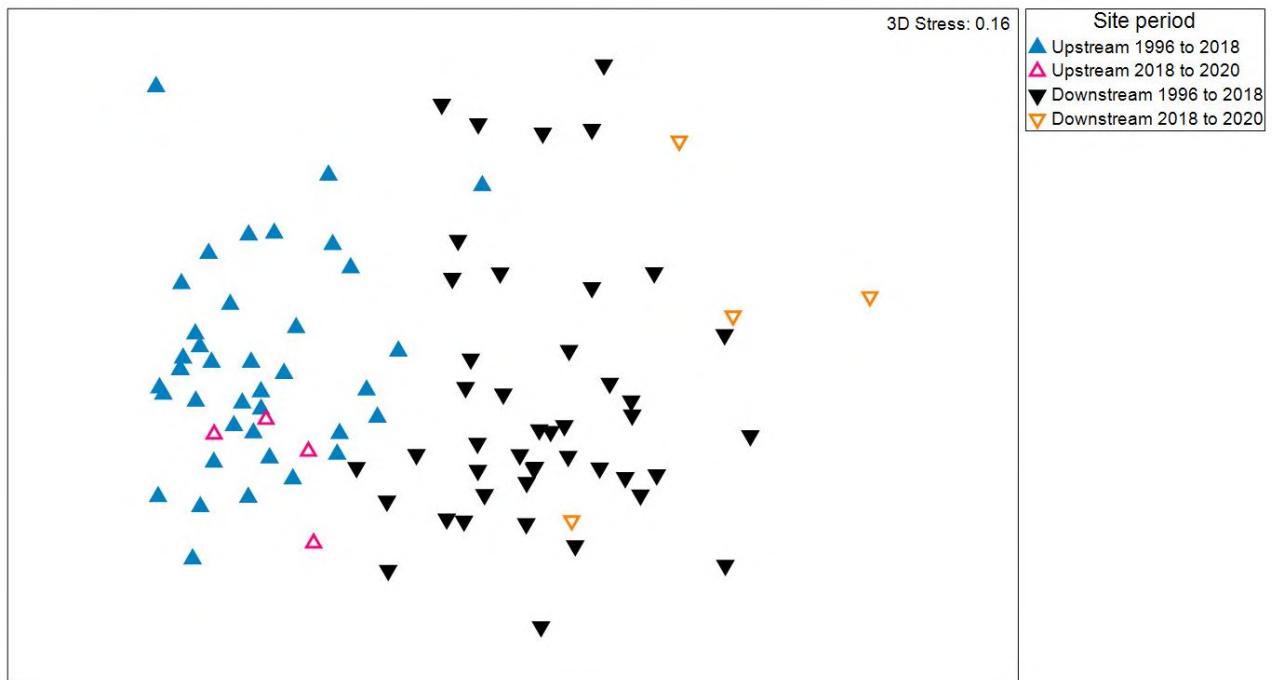


Figure N-36 Dimensions 1 and 2 of three-dimensional ordination plot of freshwater macroinvertebrate riffle habitat community structure of upstream-downstream sites of Calna Creek near Hornsby Heights WWTP

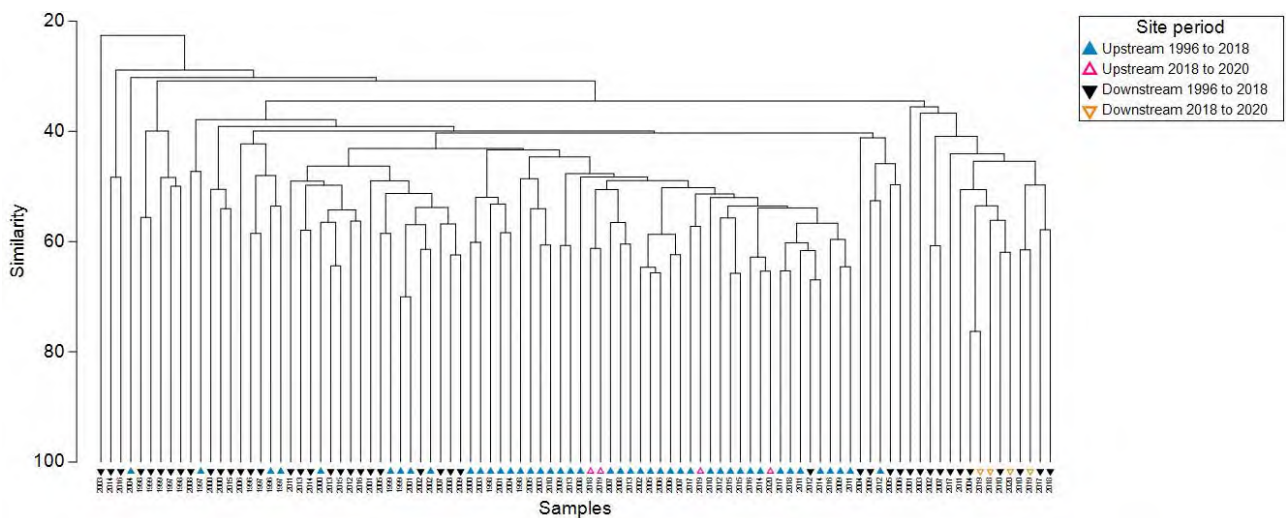


Figure N-37 Tree diagram of freshwater macroinvertebrate edge habitat community structure of upstream-downstream sites of Calna Creek near Hornsby Heights WWTP

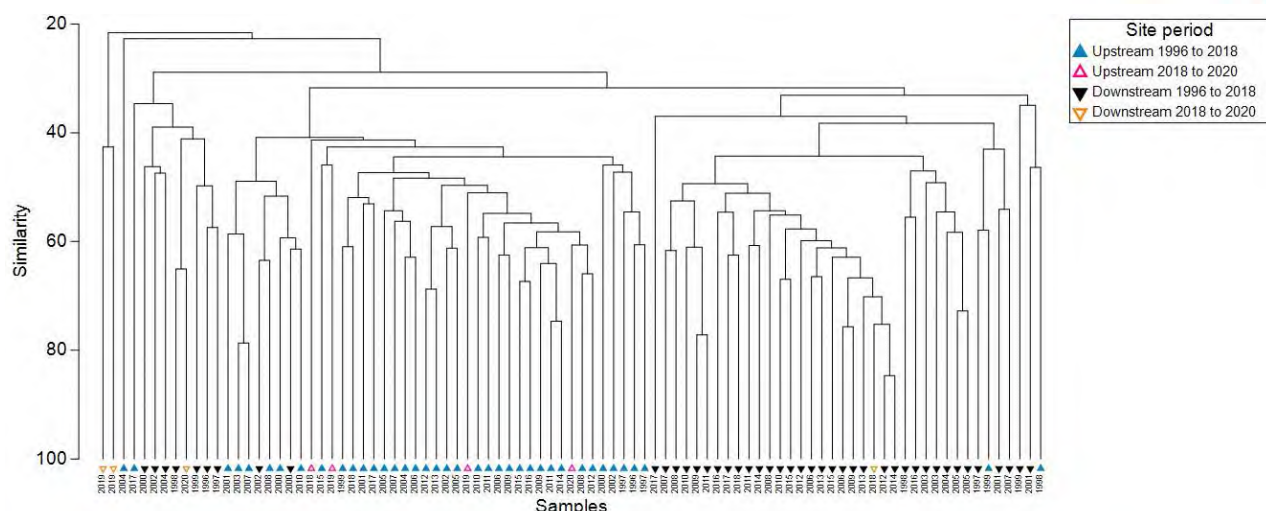


Figure N-38 Tree diagram of freshwater macroinvertebrate riffle habitat community structure of upstream-downstream sites of Calna Creek near Hornsby Heights WWTP

Table N-47 ANOSIM test of 'Site' factor for edge habitat of Calna Creek near Hornsby Heights WWTP

Tests for differences between unordered Site groups

Global Test

Sample statistic (R): 0.36

Significance level of sample statistic: 0.01%

Number of permutations: 9999 (Random sample from a large number)

Number of permuted statistics greater than or equal to R: 0

Table N-48 ANOSIM test of 'Site' factor for riffle habitat of Calna Creek near Hornsby Heights WWTP

Tests for differences between unordered Site groups

Global Test

Sample statistic (R): 0.586

Significance level of sample statistic: 0.01%

Number of permutations: 9999 (Random sample from a large number)

Number of permuted statistics greater than or equal to R: 0

Table N-49 PERMANOVA test of 'Site' and 'Year' factors for edge habitat of Calna Creek near Hornsby Heights WWTP

Sums of squares type: Type III (partial)

Fixed effects sum to zero for mixed terms

Permutation method: Permutation of residuals under a reduced model

Number of permutations: 9999

PERMANOVA table of results

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms
Site	1	18302	18302	12.125	0.0001	9912
Year	24	52248	2177	1.4423	0.0001	9648
SitexYear	24	41229	1717.9	1.1381	0.0464	9659
Res	46	69434	1509.4			
Total	95	1.8131E+05				

Estimates of components of variation

Source	Estimate	Sq.root
S(Site)	362.72	19.045
S(Year)	173.99	13.191
S(SitexYear)	108.66	10.424
V(Res)	1509.4	38.851

Table N-50 PERMANOVA test of 'Site' and 'Year' factors for riffle habitat of Calna Creek near Hornsby Heights WWTP

Sums of squares type: Type III (partial)

Fixed effects sum to zero for mixed terms

Permutation method: Permutation of residuals under a reduced model

Number of permutations: 9999

PERMANOVA table of results

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms
Site	1	35302	35302	24.911	0.0001	9930
Year	24	52242	2176.7	1.536	0.0001	9687
SitexYear	24	43221	1800.9	1.2708	0.0023	9680
Res	41	58103	1417.1			
Total	90	1.9243E+05				

Estimates of components of variation

Source	Estimate	Sq.root
S(Site)	799.68	28.279
S(Year)	212.92	14.592
S(SitexYear)	215.13	14.667
V(Res)	1417.1	37.645



Table N-51 PERMDISP test of 'Site' factor for edge habitat of Calna Creek near Hornsby Heights WWTP

DEVIATIONS FROM CENTROID

F: 30.288 df1: 1 df2: 94

P(perm): 0.0001

MEANS AND STANDARD ERRORS

Group	Size	Average	SE
Downstream	48	43.939	0.93465
Upstream	48	37.367	0.74336

Table N-52 PERMDISP test of 'Site' factor for riffle habitat of Calna Creek near Hornsby Heights WWTP

DEVIATIONS FROM CENTROID

F: 2.7061 df1: 1 df2: 89

P(perm): 0.1294

MEANS AND STANDARD ERRORS

Group	Size	Average	SE
Downstream	48	41.739	1.2992
Upstream	43	38.932	1.0705



Table N-53 ANOSIM test of 'Site period' for edge habitat of Calna Creek near Hornsby Heights WWTP

Tests for differences between unordered Site period groups

Global Test

Sample statistic (R): 0.299

Significance level of sample statistic: 0.01%

Number of permutations: 9999 (Random sample from a large number)

Number of permuted statistics greater than or equal to R: 0

Pairwise Tests

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
Downstream 1996 to 2018, Downstream 2018 to 2020	-0.078	67.6	194580	9999	6762
Downstream 1996 to 2018, Upstream 1996 to 2018	0.327	0.01	Very large	9999	0
Downstream 1996 to 2018, Upstream 2018 to 2020	0	46.9	194580	9999	4689
Downstream 2018 to 2020, Upstream 1996 to 2018	0.851	0.01	194580	9999	0
Downstream 2018 to 2020, Upstream 2018 to 2020	0.948	2.9	35	35	1
Upstream 1996 to 2018, Upstream 2018 to 2020	0.003	44.8	194580	9999	4478

Table N-54 ANOSIM test of 'Site period' for riffle habitat of Calna Creek near Hornsby Heights WWTP

Tests for differences between unordered Site period groups

Global Test

Sample statistic (R): 0.579

Significance level of sample statistic: 0.01%

Number of permutations: 9999 (Random sample from a large number)

Number of permuted statistics greater than or equal to R: 0

Pairwise Tests

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
Downstream 1996 to 2018, Downstream 2018 to 2020	0.393	1.5	194580	9999	147
Downstream 1996 to 2018, Upstream 1996 to 2018	0.603	0.01	Very large	9999	0
Downstream 1996 to 2018, Upstream 2018 to 2020	0.574	0.07	194580	9999	6
Downstream 2018 to 2020, Upstream 1996 to 2018	0.936	0.02	123410	9999	1
Downstream 2018 to 2020, Upstream 2018 to 2020	0.823	2.9	35	35	1
Upstream 1996 to 2018, Upstream 2018 to 2020	0.162	15.9	123410	9999	1587

Table N-55 Genera subset whose multivariate pattern matches full genera set of the edge habitat Calna Creek near Hornsby Heights WWTP

Subset of 36 (correlation 0.950) genera from edge habitat whose pattern matches that of the full set of 139 genera identified with same subset found on seven runs from 50 random start runs. Each run was based on three randomly selected genera. Genera were:

Chironomidae *Chironomus*, Physidae *Physella*, Chironomidae *Cricotopus*, Chironomidae *Cryptochironomus*, Chironomidae *Dicrotendipes*, Coenagrionidae *Austroagrion*, DugesIIDae *Cura*, Glossiphoniidae *Helobdella*, Lumbriculidae *Lumbriculus*, Lymnaeidae *Pseudosuccinea*, Naididae *Branchiura*, Planorbidae *Ferrissia*, Argiolestidae *Austroargiolestes*, Chironomidae *Microtendipes*, Chironomidae *Polypedilum*, Chironomidae *Procladius*, Chironomidae *Rheocricotopus*, Corduliidae *Hemicordulia*, Tateidae *Potamopyrgus*, Ceratopogonidae *Bezzia*, Elmidae *Notriolus*, Elmidae *Simsonia*, Gomphidae *Austrogomphus*, Hydroptilidae *Hellyethira*, Notonectidae *Enithares*, Chironomidae *Paramerina*, Chironomidae *Riethia*, Corydalidae *Archichauliodes*, Elmidae *Kingolus*, Gerridae *Tenagogerris*, Notonectidae *Anisops*, Oxidae *Oxus*, Psephenidae *Sclerocyphon*, Veliidae *Microvelia*, Chironomidae *Tanytarsus*, Stratiomyidae *Odontomyia*.

Table N-56 Genera subset whose multivariate pattern matches full genera set of the riffle habitat Calna Creek near Hornsby Heights WWTP

Subset of 30 (correlation 0.951) genera from riffle habitat whose pattern matches that of the full set of 105 genera identified with same subset found on 14 runs from 50 random start runs. Each run was based on three randomly selected genera. Genera were:

Chironomidae *Chironomus*, Physidae *Physella*, Chironomidae *Cricotopus*, DugesIIDae *Cura*, Lumbriculidae *Lumbriculus*, Simuliidae *Simulium*, Argiolestidae *Austroargiolestes*, Chironomidae *Polypedilum*, Chironomidae *Procladius*, Chironomidae *Rheocricotopus*, Chironomidae *Rheotanytarsus*, Gelastocoridae *Nerthra*, Hydropsychidae *Cheumatopsyche*, Tateidae *Potamopyrgus*, Ceratopogonidae *Bezzia*, Elmidae *Notriolus*, Elmidae *Simsonia*, Hydroptilidae *Hellyethira*, Aeshnidae *Austroaeschna*, Chironomidae *Parakiefferiella*, Chironomidae *Paratanytarsus*, Corydalidae *Archichauliodes*, Elmidae *Kingolus*, Psephenidae *Sclerocyphon*, Antipodoecidae *Antipodoecia*, Calamoceratidae *Anisocentropus*, Elmidae *Austrolimnius*, Gomphidae *Hemigomphus*, Philopotamidae *Chimarra*, Stratiomyidae *Odontomyia*.

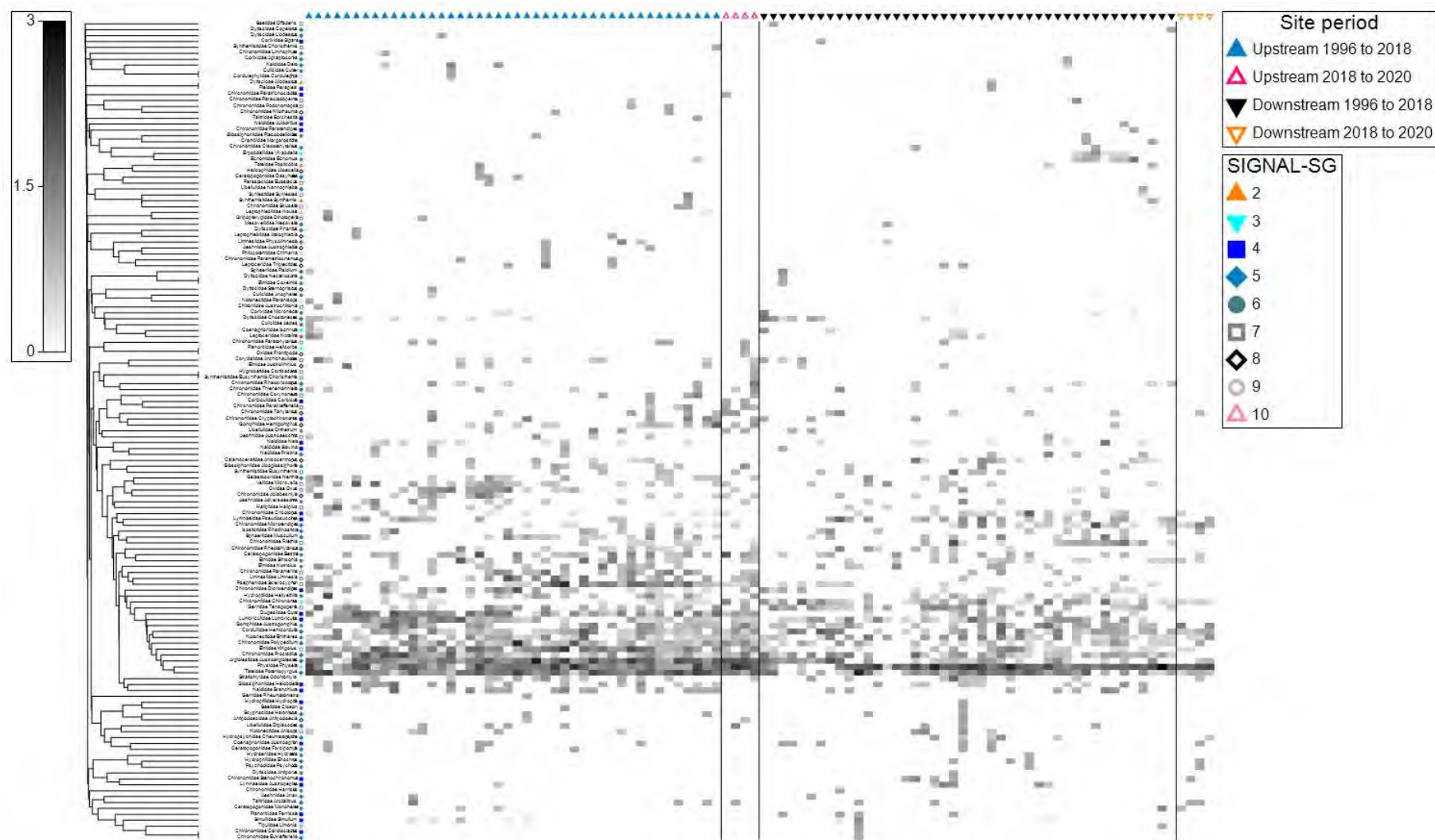


Figure N-39 Shade plot of freshwater macroinvertebrate edge habitat community structure of upstream-downstream sites of Calna Creek near Hornsby Heights WWTP

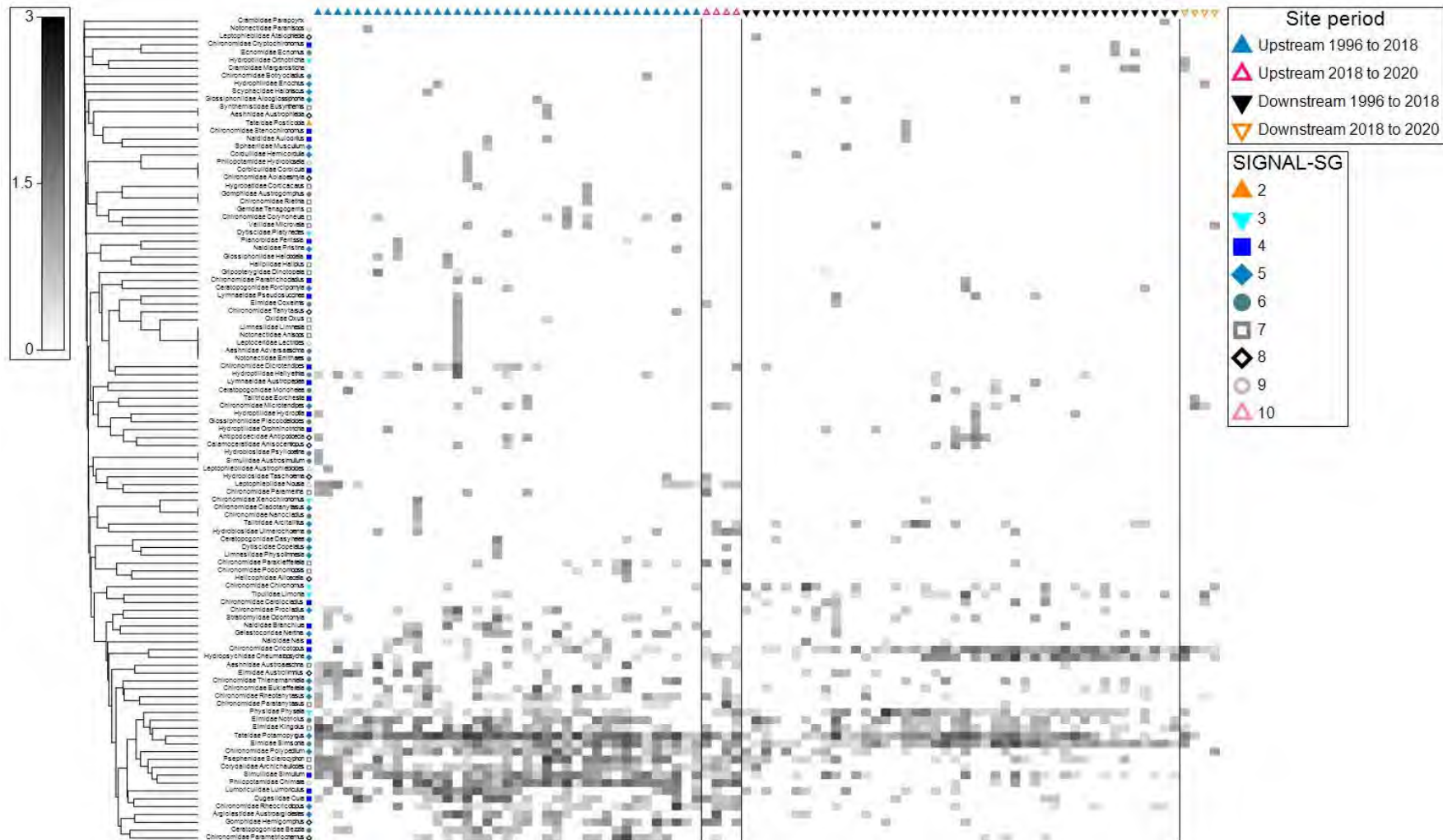


Figure N-40 Shade plot of freshwater macroinvertebrate riffle habitat community structure of upstream-downstream sites of Calna Creek near Hornsby Heights WWTP

Stream health near West Hornsby WWTP

The SIGNAL-SG plot for Waitara Creek provided an assessment of stream health. This plot was based on macroinvertebrate identification and counting results expressed as SIGNAL-SG scores and allows a visual comparison of data collected from 2019–20 against that collected between 1996 and 2019. This comparison suggests mean stream health of both sites was similar to the preceding 2018-19 year but the range of returned SIGNAL-SG scores was tighter for both sites in 2019-20. This outcome suggested wastewater discharge from West Hornsby WWTP did have a measurable negative impact on stream health during 2019-20 (Figure N-41).

A comparison of the upstream-downstream SIGNAL-SG scores for 2019-20 samples under a t-test returned a significant test outcome (Table N-57) and confirmed the visual trend of little overlap in the range of stream health between upstream and downstream sites in 2019-20.

As a measurable negative impact on downstream stream health was evident, further data analysis was undertaken.

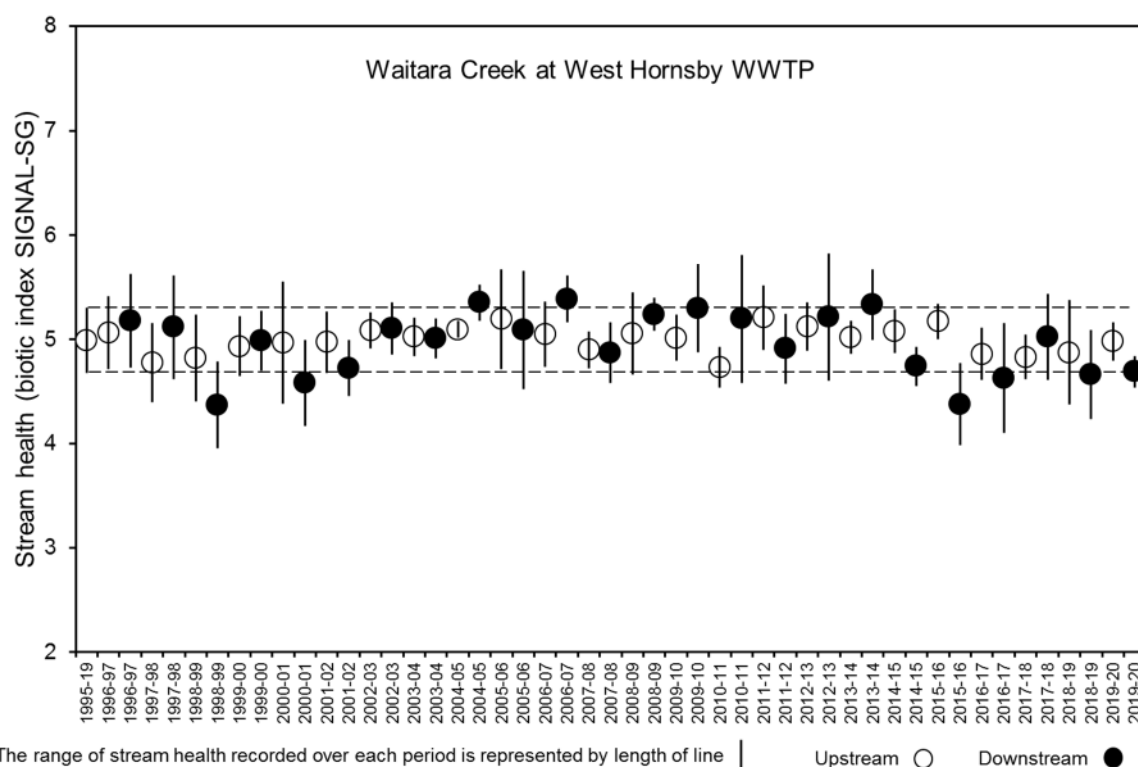


Figure N-41 Stream health of Waitara Creek near West Hornsby WWTP

Table N-57 t-test of upstream-downstream SIGNAL-SG scores of 2019-20 samples from Waitara Creek near West Hornsby WWTP

Method	Variances	DF	t Value	Pr > t
Pooled	Equal	10	-3.03	0.0127

Equality of Variances				
Method	Num DF	Den DF	F Value	Pr > F
Folded F	5	5	1.46	0.6861



Both edge and pool rock habitats were collected consistently enough at upstream-downstream sites on the same sampling occasions to allow a multivariate analysis for the monitoring period of 1996 to 2020.

Abutting groups of samples were evident in the three-dimensional nMDS ordination plot of the Waitara Creek edge habitat (Figure N-42). The ordination pattern was confirmed in the corresponding tree diagram (Figure N-44) from classification analysis where the sixth division separated most of the upstream and downstream samples. The pool rock habitat displayed a slightly overlapping pattern, with more recent (2017-2020) downstream samples grouped with other more disparate downstream samples that were generally collected from more later years (Figure N-45).

Shade plot patterns display a smaller set of taxa for each habitat at the downstream site (Figure N-46 and Figure N-47). The BVSTEP routine was used to find a subset of taxa whose multivariate pattern matched that of the full dataset with 34 taxa identified for the edge habitat (Table N-66) and 27 taxa for the pool rock habitat (Table N-67). These subsets of taxa reflect those taxa which formed the main visual patterns in the respective shade plots.

The PERMDISP analysis indicated a significantly different pattern of dispersion (spacing between same samples) for the upstream and downstream sites of the edge and pool rock habitats (Table N-62 and Table N-63). This suggests the variability in taxonomic composition of samples collected over time was different for upstream and downstream sites through the period 1996 to 2020. This outcome suggests subsequent edge and pool rock habitat results of ANOSIM tests are describing both the variability in taxonomic composition of samples over time as well as community composition variability between the upstream and downstream sites.

An ANOSIM test was run on the factor 'Site'. The returned R-values were at a mid-range level for edge (Table N-58) and at a low-range level for pool rock (Table N-59). These R-value results suggest site specific assemblages were more distinguishable for the edge habitat and less distinguishable for the pool rock habitat.

To further explore community structure, hypothesis testing was conducted with a PERMANOVA model. This model comprised the fixed factors 'Site' and 'Year' with 'Year' representing samples collected between 1996 and 2020 and 'Site' having two levels, upstream and downstream. A statistically non-significant 'Site x Year' interaction was returned for both the edge and pool rock habitats (Table N-60 and Table N-61). These non-significant results allowed us to view the 'Site' and 'Year' results. Significant results were returned for 'Site' and 'Year' for both habitats.

A second run of ANOSIM based on 'Site-Period' sample groups displayed in the above ordination plots (Figure N-42 and Figure N-43) returned a significant global mid-range R-value (0.46) for the edge habitat. In the resulting pairwise comparisons, three of the six tests returned significant R-values at a mid to high level (Table N-64). A slightly lower mid-range global R-value of 0.386 was returned for the pool rock habitat. A corresponding pairwise test for both the edge and pool rock habitats returned high level significant R-value for the comparison of 2017 to 2020 downstream site to the 1996 to 2017 upstream site time periods (Table N-65). This test outcome likely reflects disturbance by wastewater discharge as it is above the 0.66 R-value determined by Besley and Chessman (2008) that represents natural habitat differences between sites on the same stream.

SIGNAL-SG and multivariate testing outcomes suggest downstream community structure in Waitara Creek was altered by wastewater discharge from West Hornsby WWTP in the more recent period.

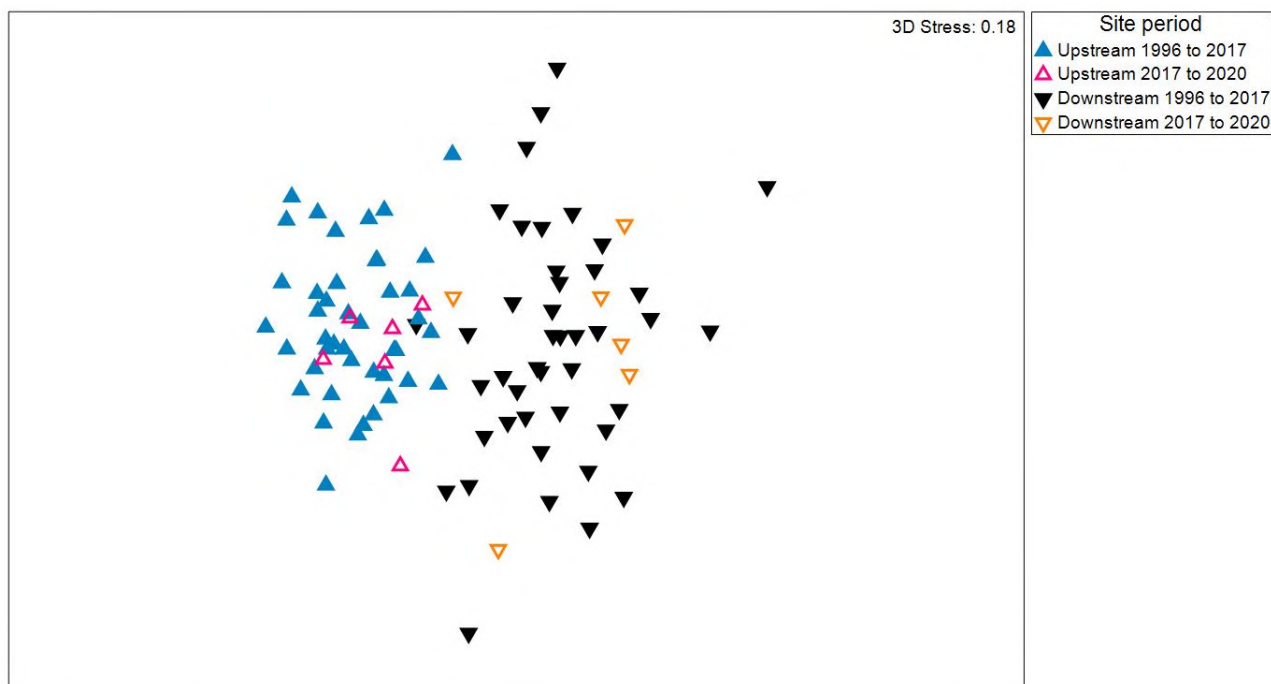


Figure N-42 Dimensions 1 and 2 of three-dimensional ordination plot of freshwater macroinvertebrate edge habitat community structure of upstream-downstream sites of Waitara Creek near West Hornsby WWTP

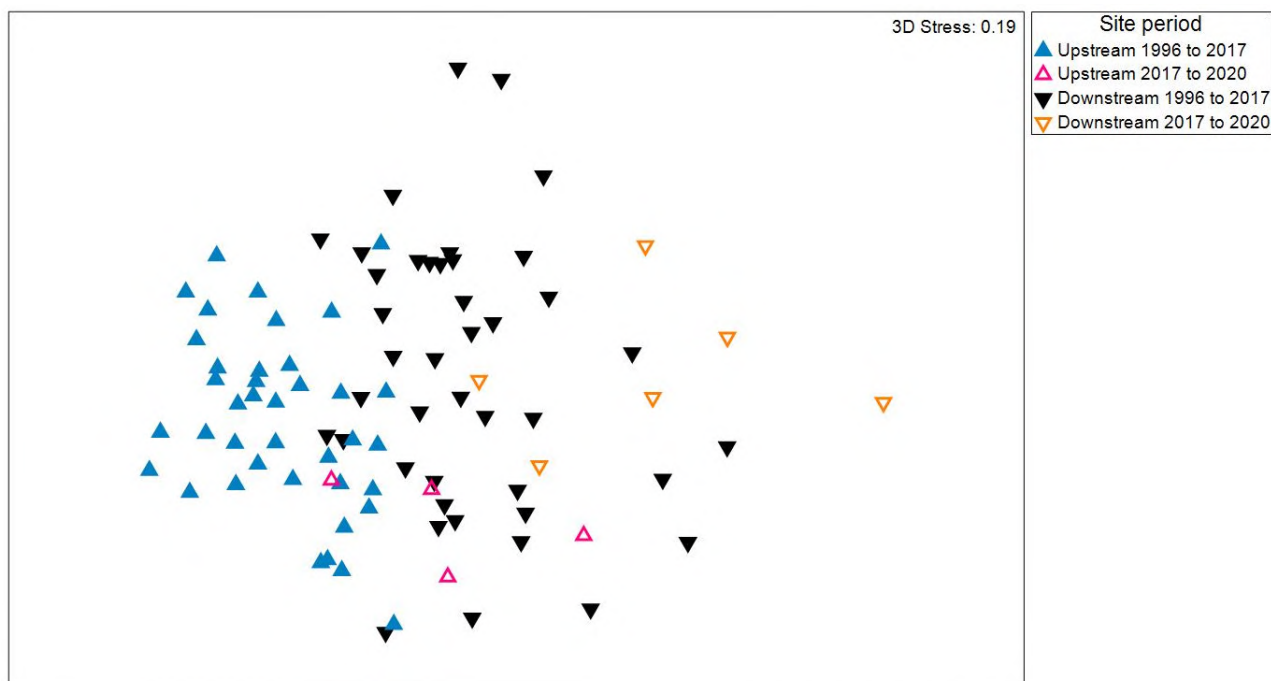


Figure N-43 Dimensions 1 and 2 of three-dimensional ordination plot of freshwater macroinvertebrate pool rock habitat community structure of upstream-downstream sites of Waitara Creek near West Hornsby WWTP

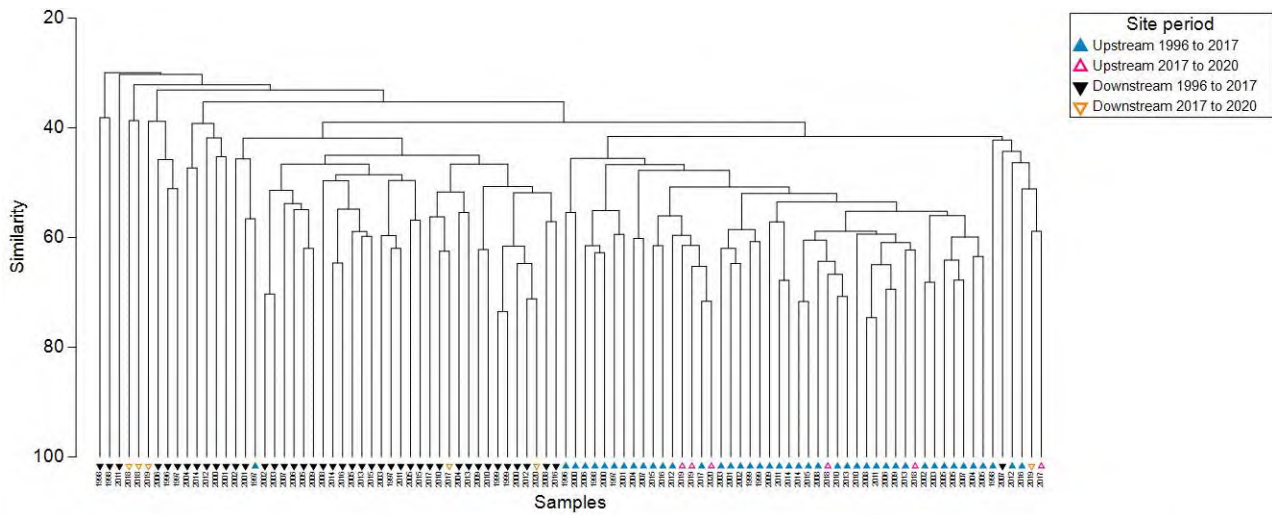


Figure N-44 Tree diagram of freshwater macroinvertebrate edge habitat community structure of upstream-downstream sites of Waitara Creek near West Hornsby WWTP

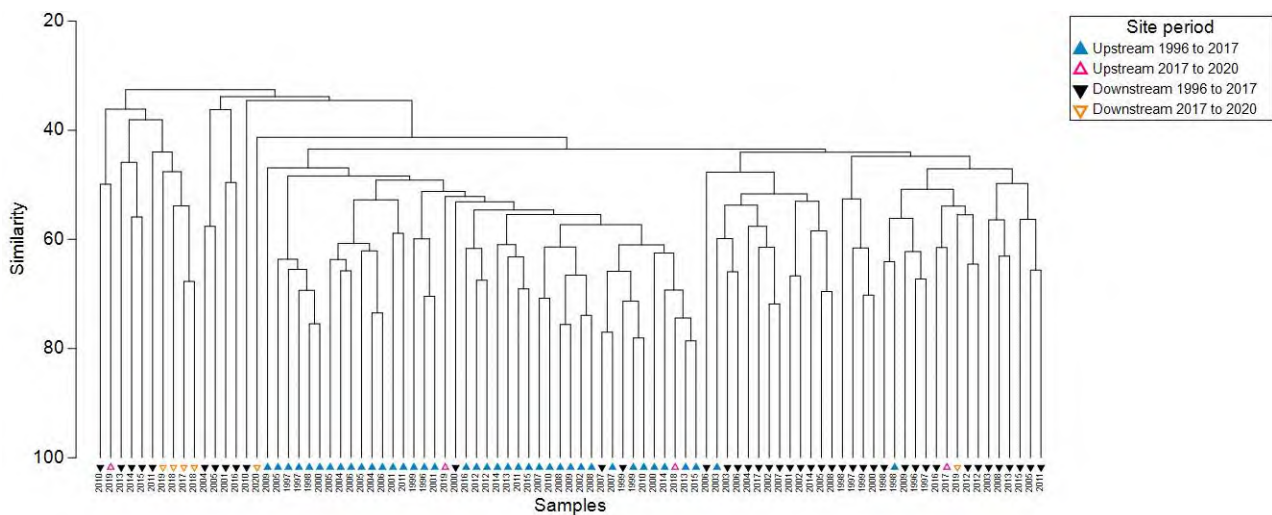


Figure N-45 Tree diagram of freshwater macroinvertebrate pool rock habitat community structure of upstream-downstream sites of Waitara Creek near West Hornsby WWTP



Table N-58 ANOSIM test of 'Site' factor for edge habitat of Waitara Creek near West Hornsby WWTP

Analysis of Similarities

Site levels

Downstream

Upstream

Tests for differences between unordered Site groups

Global Test

Sample statistic (R): 0.502

Significance level of sample statistic: 0.01%

Number of permutations: 9999 (Random sample from a large number)

Table N-59 ANOSIM test of 'Site' factor for pool rock habitat of Waitara Creek near West Hornsby WWTP

Analysis of Similarities

Site levels

Downstream

Upstream

Tests for differences between unordered Site groups

Global Test

Sample statistic (R): 0.319

Significance level of sample statistic: 0.01%

Number of permutations: 9999 (Random sample from a large number)

Table N-60 PERMANOVA test of 'Site' and 'Year' factors for edge habitat of Waitara Creek near West Hornsby WWTP

Sums of squares type: Type III (partial)

Fixed effects sum to zero for mixed terms

Permutation method: Permutation of residuals under a reduced model

Number of permutations: 9999

PERMANOVA table of results

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms
Site	1	24278	24278	19.54	0.0001	9923
Year	24	55426	2309.4	1.8588	0.0001	9657
SitexYear	24	33547	1397.8	1.125	0.0717	9676
Res	48	59637	1242.4			
Total	97	1.7377E+05				

Estimates of components of variation

Source	Estimate	Sq.root
S(Site)	491.42	22.168
S(Year)	272.54	16.509
S(SitexYear)	79.358	8.9083
V(Res)	1242.4	35.248

Table N-61 PERMANOVA test of 'Site' and 'Year' factors for pool rock habitat of Waitara Creek near West Hornsby WWTP

Sums of squares type: Type III (partial)

Fixed effects sum to zero for mixed terms

Permutation method: Permutation of residuals under a reduced model

Number of permutations: 9999

PERMANOVA table of results

Source	df	SS	MS	Pseudo-F	P(perm)	Unique perms
Site	1	15456	15456	12.956	0.0001	9918
Year	24	51862	2160.9	1.8114	0.0001	9699
SitexYear	23	30808	1339.5	1.1228	0.1131	9716
Res	42	50106	1193			
Total	90	1.5306E+05				

Estimates of components of variation

Source	Estimate	Sq.root
S(Site)	342.54	18.508
S(Year)	272.75	16.515
S(SitexYear)	80.082	8.9488
V(Res)	1193	34.54



Table N-62 PERMDISP test of 'Site' factor for edge habitat of Waitara Creek near West Hornsby WWTP

DEVIATIONS FROM CENTROID

F: 32.332 df1: 1 df2: 96

P(perm): 0.0001

MEANS AND STANDARD ERRORS

Group	Size	Average	SE
Downstream	49	41.752	0.9345
Upstream	49	34.939	0.74991

Table N-63 PERMDISP test of 'Site' factor for pool rock habitat of Waitara Creek near West Hornsby WWTP

DEVIATIONS FROM CENTROID

F: 18.989 df1: 1 df2: 89

P(perm): 0.0002

MEANS AND STANDARD ERRORS

Group	Size	Average	SE
Downstream	48	40.739	0.96506
Upstream	43	34.716	0.98587



Table N-64 ANOSIM test of 'Site period' factor for edge habitat of Waitara Creek near West Hornsby WWTP

Global Test

Sample statistic (R): 0.46

Significance level of sample statistic: 0.01%

Number of permutations: 9999 (Random sample from a large number)

Number of permuted statistics greater than or equal to R: 0

Pairwise Tests

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
Downstream 1996 to 2017, Downstream 2017 to 2020	0.241	3.8	13983816	9999	381
Downstream 1996 to 2017, Upstream 1996 to 2017	0.512	0.01	Very large	9999	0
Downstream 1996 to 2017, Upstream 2017 to 2020	0.233	3.5	13983816	9999	353
Downstream 2017 to 2020, Upstream 1996 to 2017	0.913	0.01	13983816	9999	0
Downstream 2017 to 2020, Upstream 2017 to 2020	0.489	0.2	462	462	1
Upstream 1996 to 2017, Upstream 2017 to 2020	0.04	36	13983816	9999	3603

Table N-65 ANOSIM test of 'Site period' factor for pool rock habitat of Waitara Creek near West Hornsby WWTP

Global Test

Sample statistic (R): 0.386

Significance level of sample statistic: 0.01%

Number of permutations: 9999 (Random sample from a large number)

Number of permuted statistics greater than or equal to R: 0

Pairwise Tests

Groups	R Statistic	Significance Level %	Possible Permutations	Actual Permutations	Number >= Observed
Downstream 1996 to 2017, Downstream 2017 to 2020	0.315	0.6	12271512	9999	54
Downstream 1996 to 2017, Upstream 1996 to 2017	0.345	0.01	Very large	9999	0
Downstream 1996 to 2017, Upstream 2017 to 2020	0.186	10.7	163185	9999	1066
Downstream 2017 to 2020, Upstream 1996 to 2017	0.867	0.01	8145060	9999	0
Downstream 2017 to 2020, Upstream 2017 to 2020	0.524	0.5	210	210	1
Upstream 1996 to 2017, Upstream 2017 to 2020	0.335	1.8	123410	9999	182

Table N-66 Genera subset whose multivariate pattern matches full genera set of the edge habitat of Waitara Creek near West Hornsby WWTP

Subset of 34 (correlation 0.952) genera from edge habitat whose pattern matches that of the full set of 142 genera identified with same subset found on 27 runs from 50 random start runs. Each run was based on three randomly selected genera. Genera were:

Tateidae *Posticobia*, Chironomidae *Chironomus*, Erpobdellidae *Vivabdella*, Physidae *Physella*, Planorbidae *Helicorbis*, Chironomidae *Cricotopus*, Chironomidae *Dicrotendipes*, DugesIIDae *Cura*, Glossiphoniidae *Helobdella*, Lumbriculidae *Lumbriculus*, Lymnaeidae *Austropeplea*, Argiolestidae *Austroargiolestes*, Chironomidae *Polypedilum*, Chironomidae *Procladius*, Chironomidae *Rheocricotopus*, Corduliidae *Hemicordulia*, Hydrophilidae *Enochrus*, Hydropsychidae *Cheumatopsyche*, Isostictidae *Rhadinosticta*, Libellulidae *Nannophlebia*, Sphaeriidae *Musculium*, Tateidae *Potamopyrgus*, Ceratopogonidae *Bezzia*, Elmidae *Simsonia*, Gomphidae *Austrogomphus*, Hydroptilidae *Hellyethira*, Notonectidae *Enithares*, Chironomidae *Paramerina*, Elmidae *Kingolus*, Gerridae *Tenagogerris*, Oxidae *Oxus*, Psephenidae *Sclerocyphon*, Veliidae *Microvelia*, Stratiomyidae *Odontomyia*.

Table N-67 Genera subset whose multivariate pattern matches full genera set of the pool rock habitat of Waitara Creek near West Hornsby WWTP

Subset of 27 (correlation 0.952) genera from pool rock habitat whose pattern matches that of the full set of 79 genera identified with same subset found on 10 runs from 50 random start runs. Each run was based on three randomly selected genera. Genera were:

Tateidae *Posticobia*, Erpobdellidae *Vivabdella*, Physidae *Physella*, Planorbidae *Helicorbis*, Chironomidae *Cricotopus*, Chironomidae *Dicrotendipes*, DugesIIDae *Cura*, Glossiphoniidae *Helobdella*, Lumbriculidae *Lumbriculus*, Naididae *Branchiura*, Naididae *Nais*, Argiolestidae *Austroargiolestes*, Chironomidae *Cladotanytarsus*, Chironomidae *Polypedilum*, Chironomidae *Procladius*, Chironomidae *Rheocricotopus*, Glossiphoniidae *Alboglossiphonia*, Hydropsychidae *Cheumatopsyche*, Isostictidae *Rhadinosticta*, Tateidae *Potamopyrgus*, Ecnomidae *Ecnomus*, Elmidae *Notriolus*, Elmidae *Simsonia*, Hydroptilidae *Hellyethira*, Corydalidae *Archichauliodes*, Elmidae *Kingolus*, Psephenidae *Sclerocyphon*.

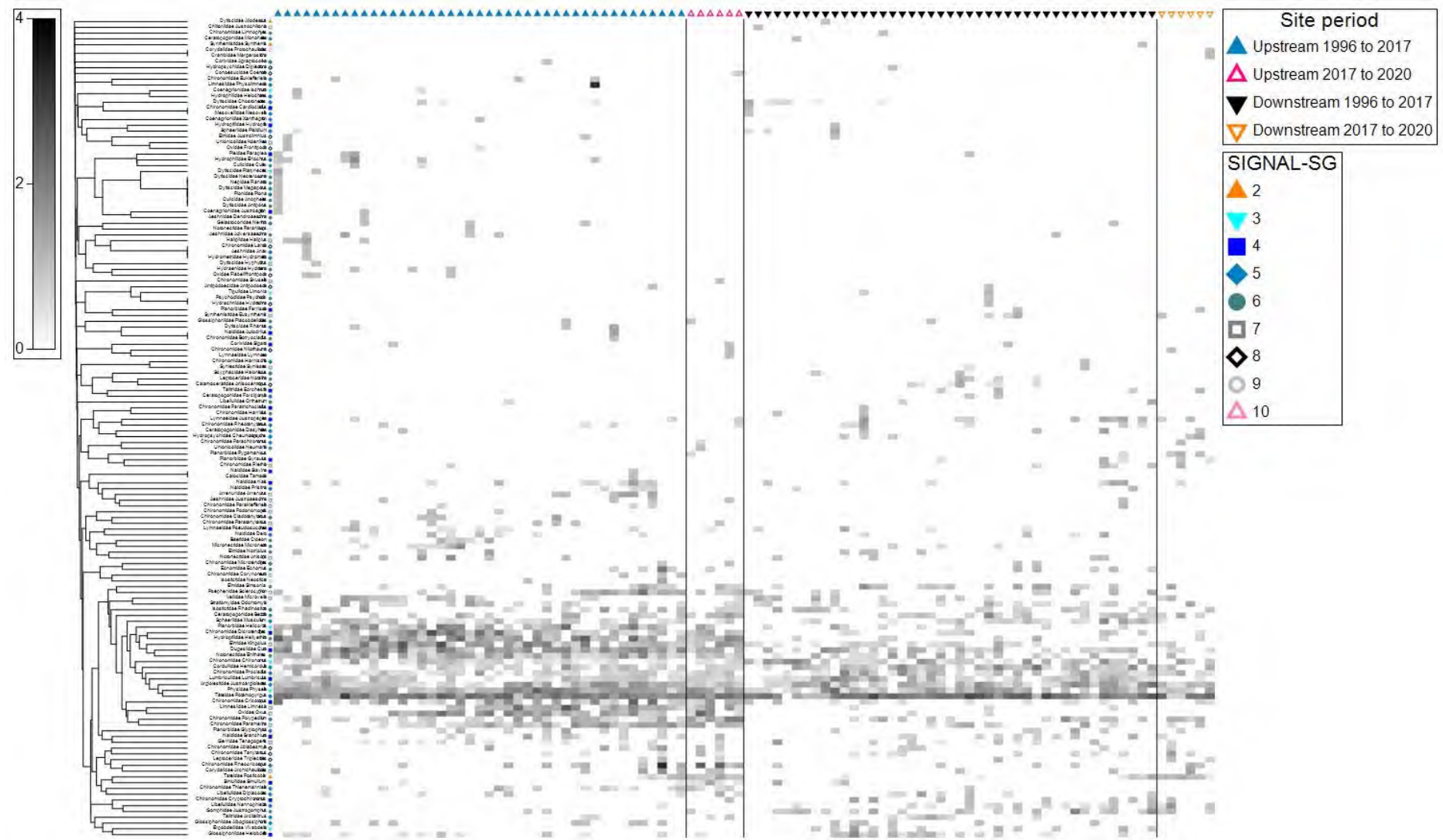


Figure N-46 Shade plot of freshwater macroinvertebrate edge habitat community structure of upstream-downstream sites of Waitara Creek near West Hornsby WWTP

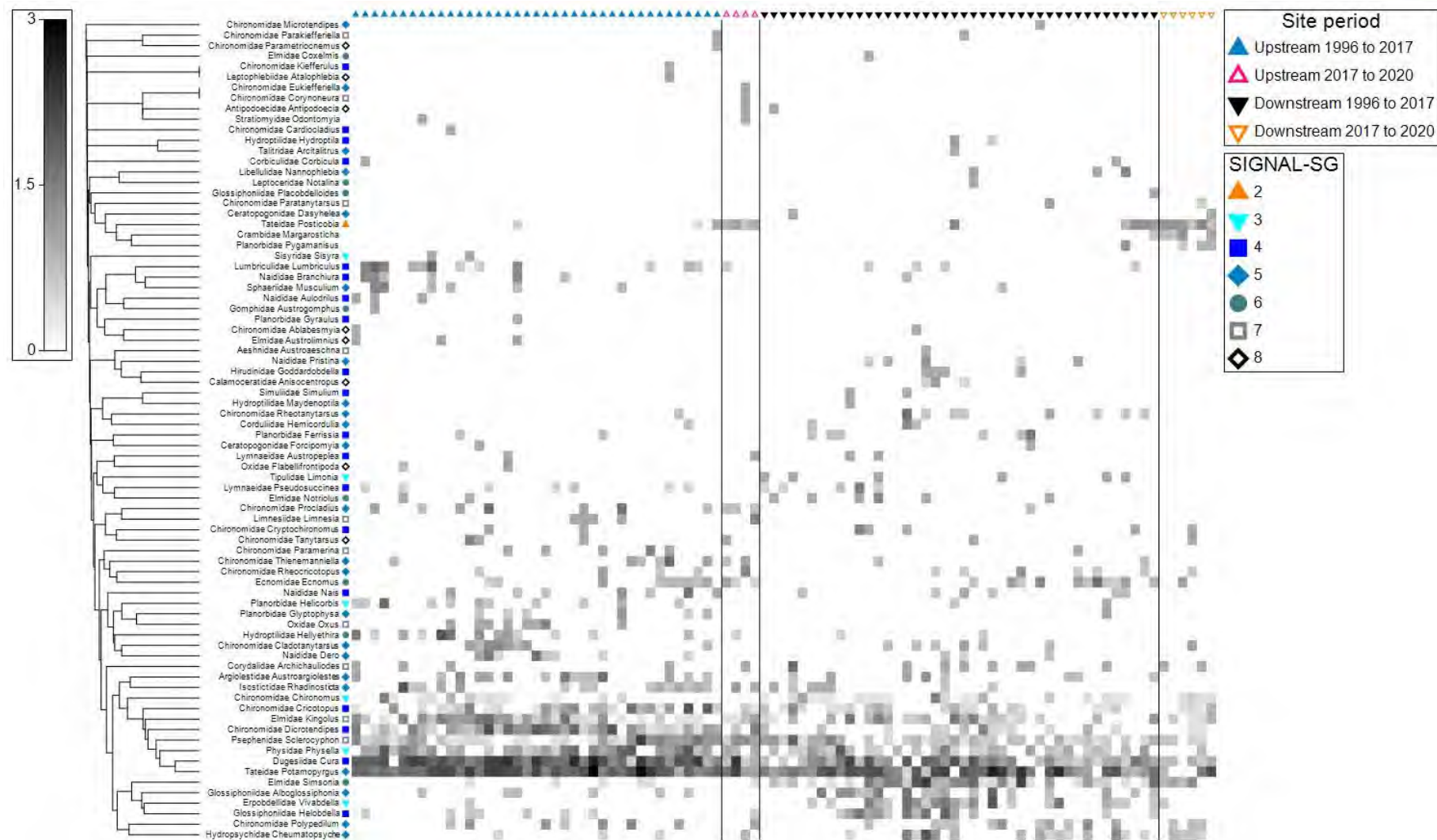
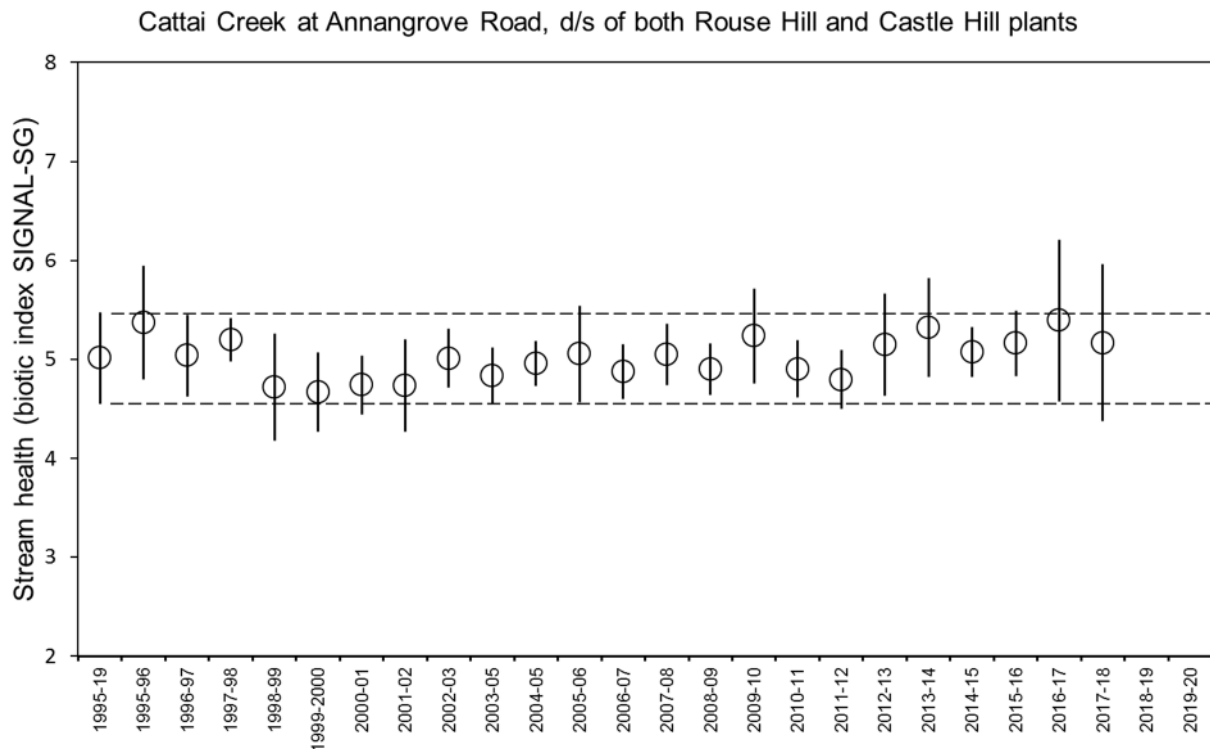


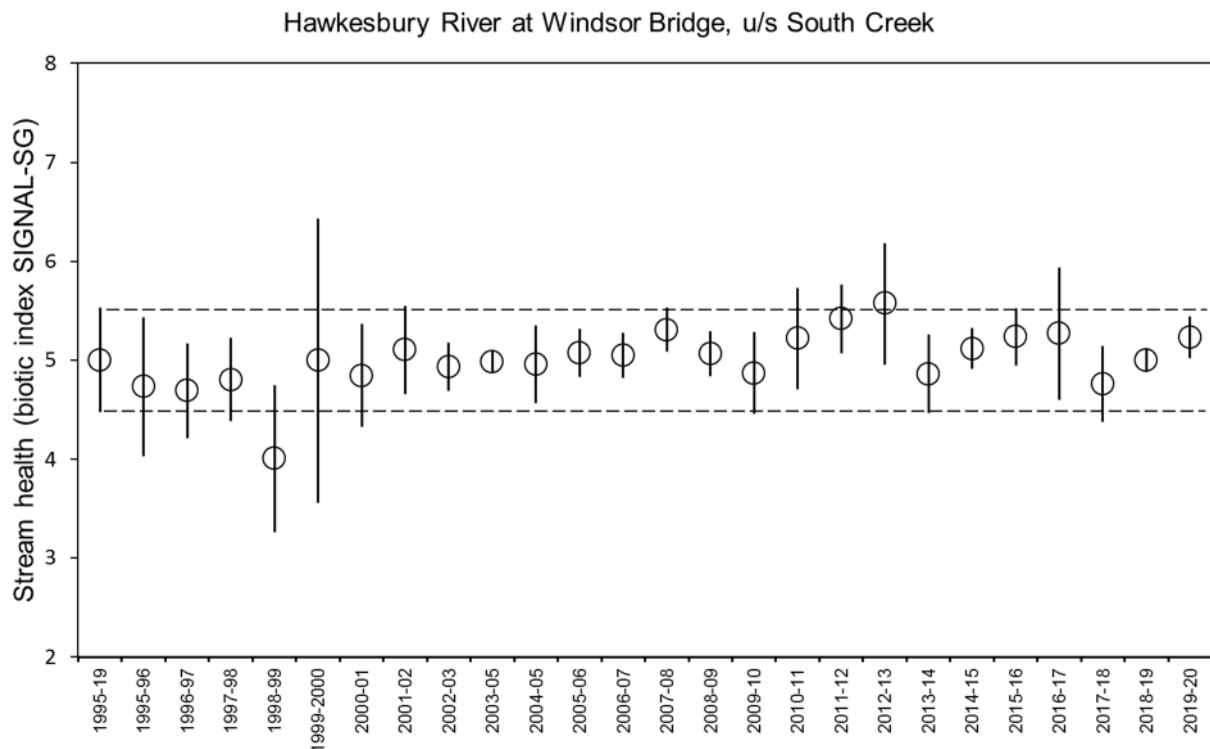
Figure N-47 Shade plot of freshwater macroinvertebrate pool rock habitat community structure of upstream-downstream sites of Waitara Creek near West Hornsby WWTP

Other sites of the Hawkesbury-Nepean River system that are only assessed under the macroinvertebrate indicator and not directly related to WWTP discharges follow.



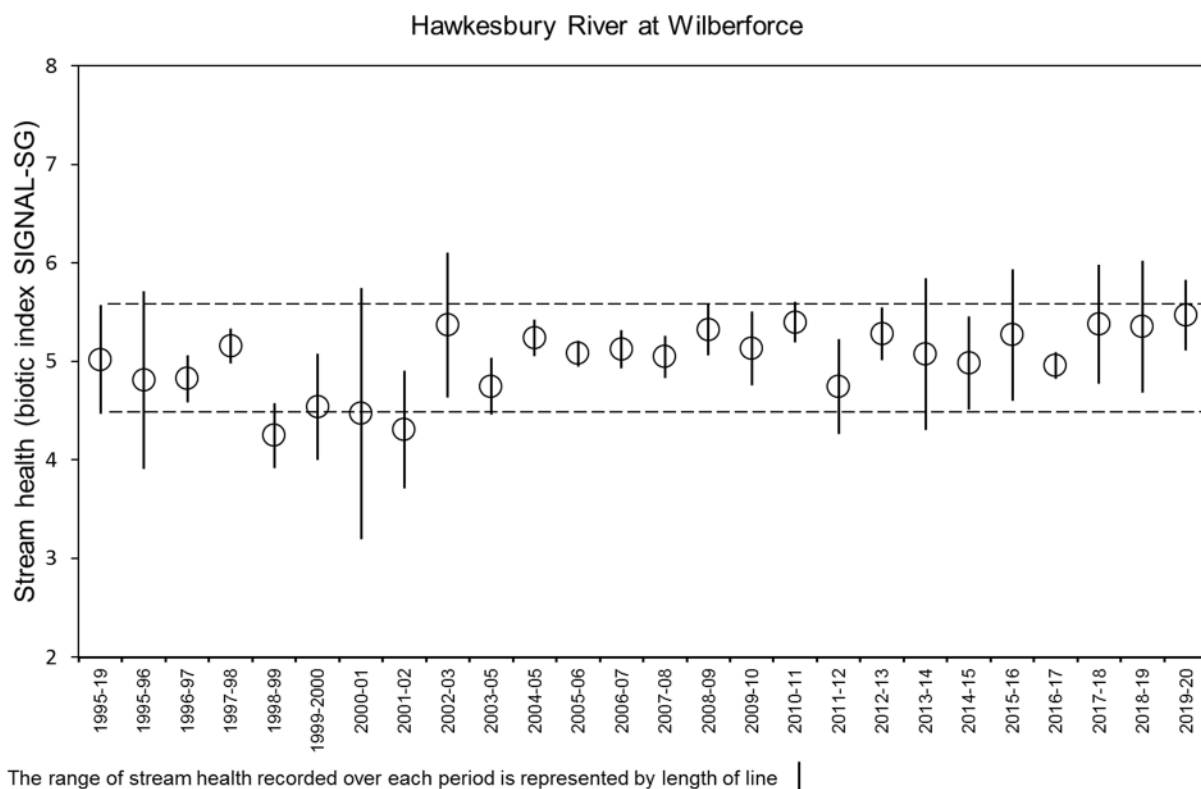
The range of stream health recorded over each period is represented by length of line

No samples were taken at NC5 in 2019-20 due to safety concerns associated with illegal dumping of asbestos near the sampling site.

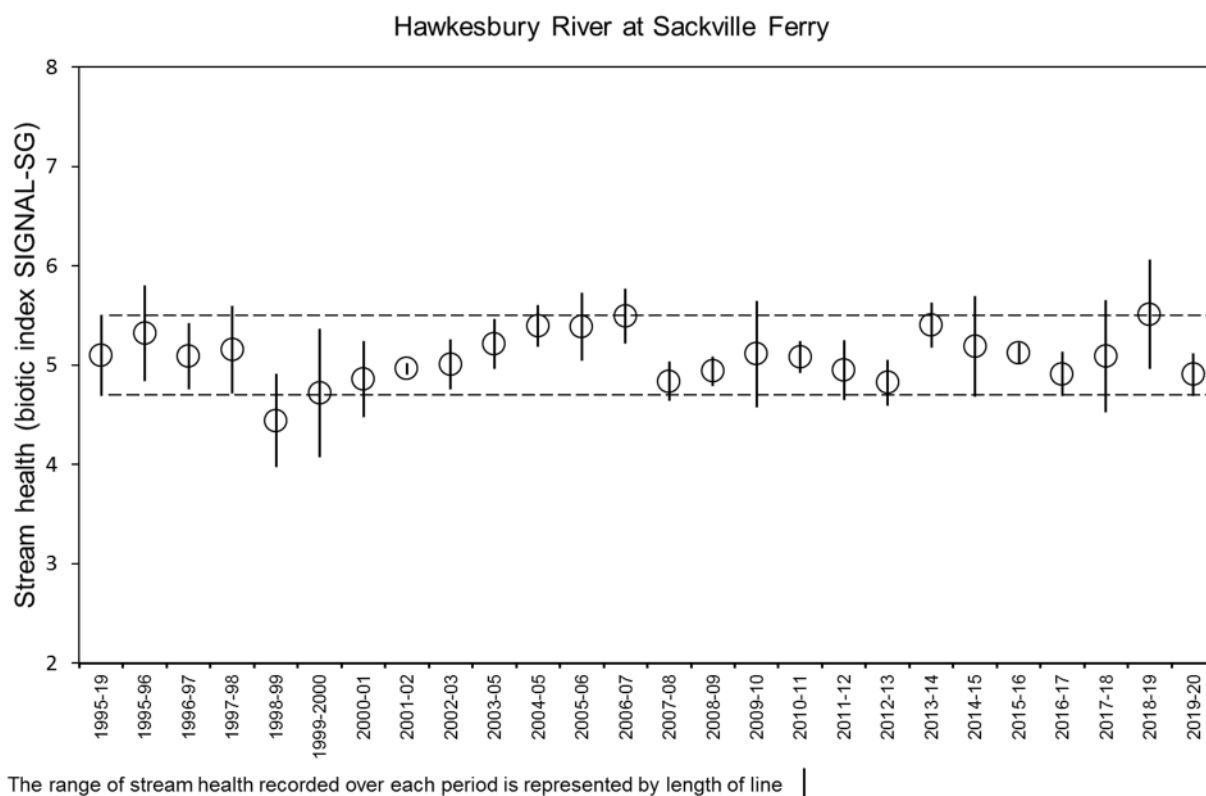


The range of stream health recorded over each period is represented by length of line

Mean stream health in 2019-20 was within the range recorded over the period back to 1995.



Mean stream health in 2019-20 was within the range recorded over the period back to 1995.



Mean stream health in 2019-20 was within the range recorded over longer period back to 1995.



Appendix O : Stream health of other Sydney rivers

Sites monitored for the macroinvertebrate indicator in freshwater streams assessed the general condition of stream health in urban areas. Among these, four are control sites located upstream of any likely impact from urban areas. Three out of the four urban sites are situated in areas just upstream of estuarine limits of the Parramatta River (PJPR), Lane Cove River (PJLC) and Georges River (GR22). The fourth urban site is situated about 5 km further up in the Georges River (GR23). The control sites were Lynch's Creek (N451) a tributary of Hawkesbury-Nepean River, Hacking River at McKell Avenue in Royal National Park (PH22), the upper Georges River system at O'Hares Creek (GE510) and Georges River at Ingleburn Reserve (GR24).

Results from 2019-20 indicate stream health for one of the four control sites (N451) was typical of natural water quality in bushland areas that do not receive urban stormwater runoff or sewer overflows (Figure O-1 and Figure O-2). The mean stream health for the Hacking River at McKell Avenue fell within the 'mild water pollution' category (Figure O-1). Additionally, mean stream health for the Georges River at Ingleburn Reserve (GR24 - control site) and O'Hares Creek were within the 'mild water pollution' category (Figure O-2).

Urban sites within the Port Jackson Rivers upstream of Lane Cove Weir (PJLC) and Parramatta Weir (PJPR) fell around the boundary of the 'mild and moderate water pollution' category (Figure O-1). Additionally, urban sites within the Georges River for 2019-20 fell within the 'mild water pollution' category (Figure O-2). These results were near the upper part of the range of stream health that has been recorded for these urban sites over the previous 1995 to 2019 period.

Results from these test sites represent the ambient condition of the combined impact of urban stormwater runoff and sewer overflows. These two influences cannot be teased apart. Pilot studies are being designed under Sydney Water's wet weather overflow program to model a stormwater control condition, which may then better define the impact of sewer overflows on urban streams than these current single site assessments.

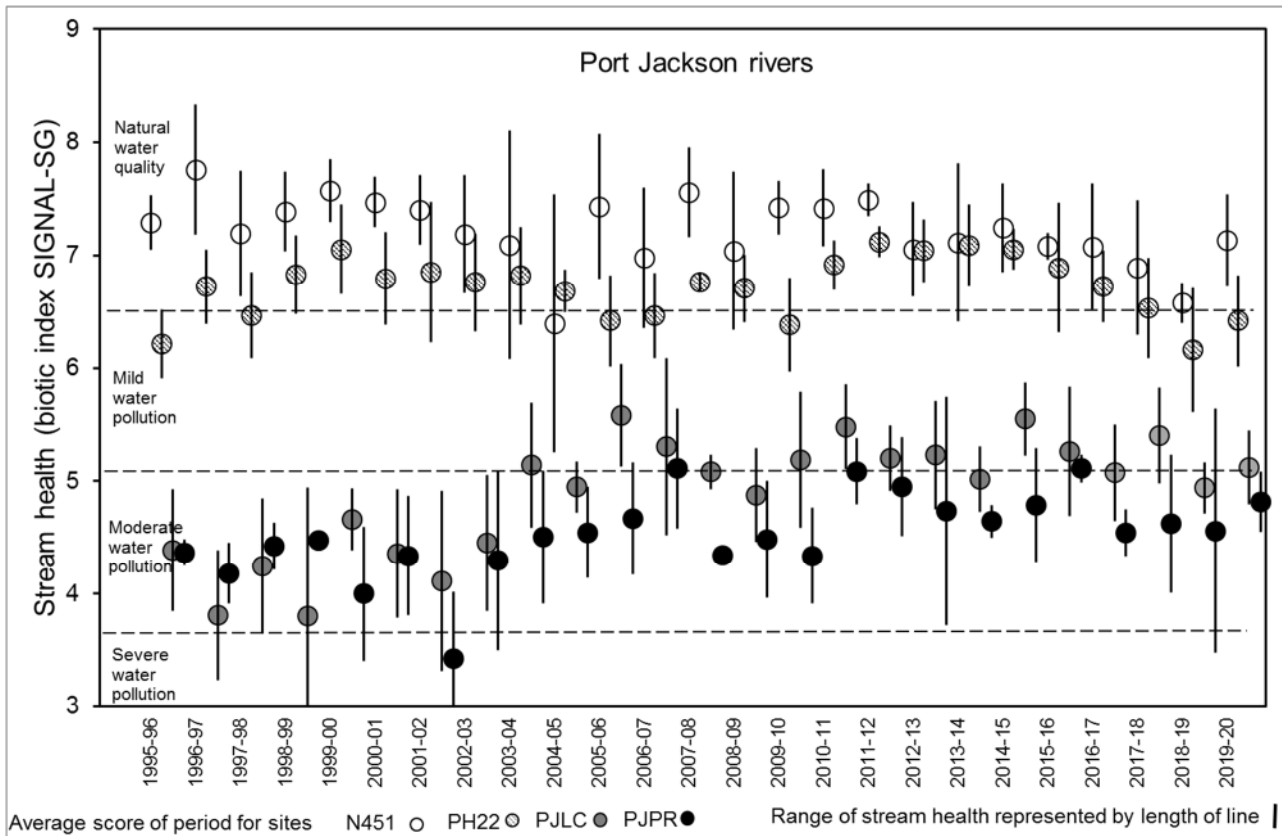


Figure O-1 Stream health of Lane Cove and Parramatta rivers in comparison to control sites

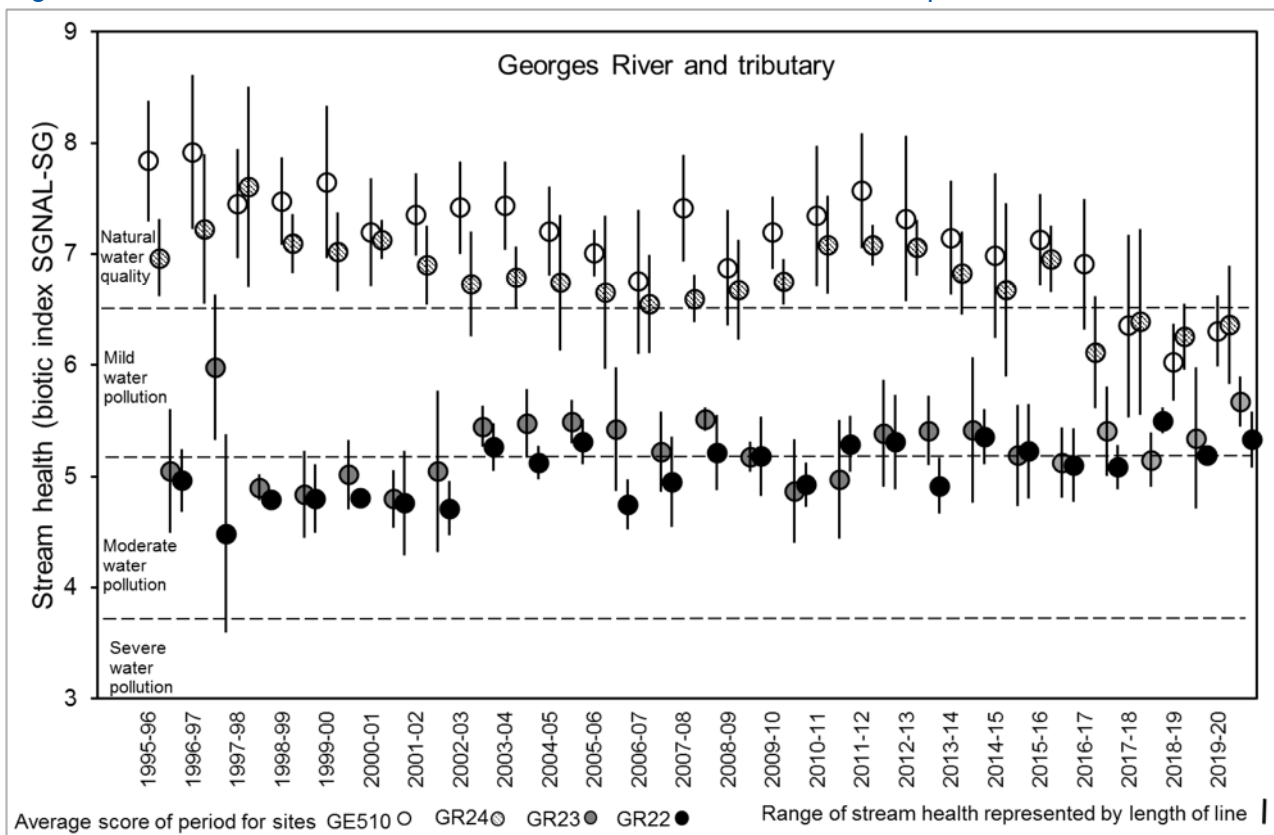


Figure O-2 Stream health of lower freshwater Georges River sites compared to control sites in the upper Georges River system

