E.0 APPENDIX E: COVE AND CANAL MODELING, SETUP AND RESULTS

E.1 Methodology

Time-series mass balance models were developed for 10 representative subdivisions to address statkeholder concerns:

Rolling Hills Shores
Arrowhead Shores
Oak Trail Shores
Ports O' Call
Indian Harbor
Nassau Bay
Sky Harbor
Port Ridglea East
Blue Water Shores
Waters Edge

Model results for each subdivision are presented in this appendix. A description of the scenarios and interpretive methods is provided in the WPP document.

E.2 Lake modeling Results

E.2.1 Rolling Hills Shores

The cove/canals connected to Rolling Hills Shores were subdivided into five segments (Figure E.1) for bacteria modeling. The contributing micro-watersheds (Figure E.2) are generally composed of shorelines adjacent to each segment, except segment 5 which includes a larger watershed contribution from undeveloped land.

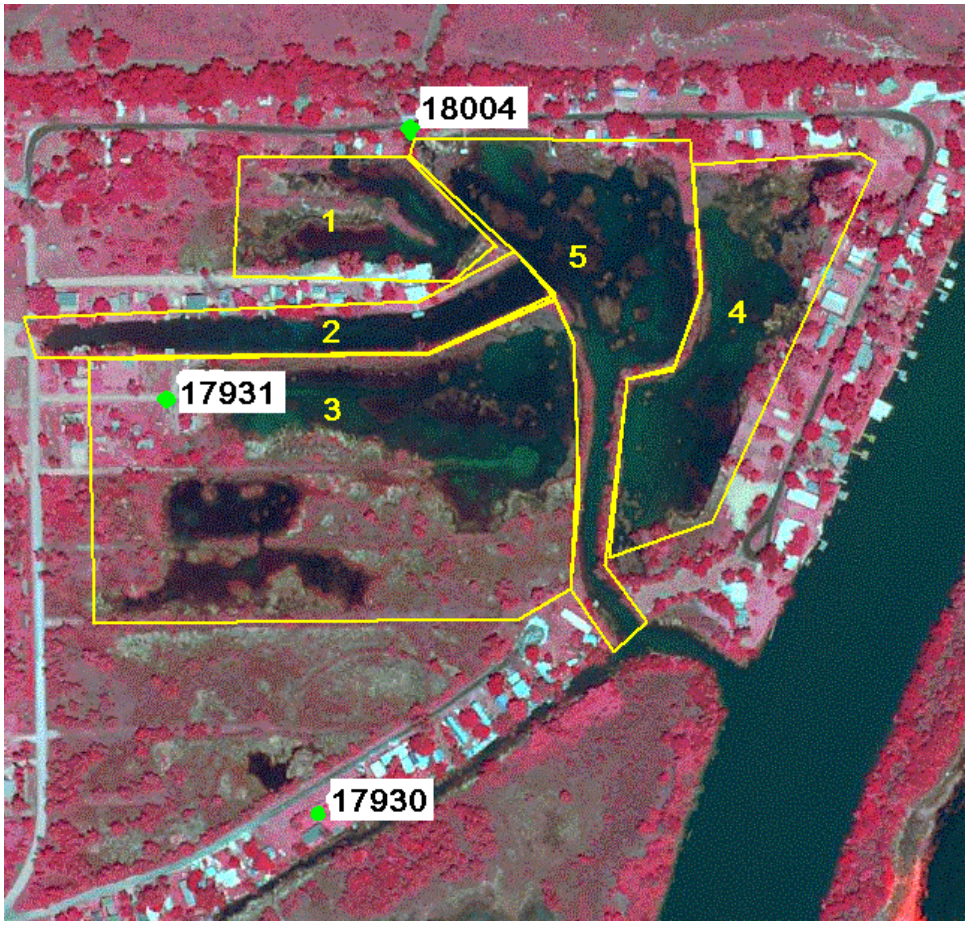


Figure E.1Canal Segmentation for Rolling Hills Shores

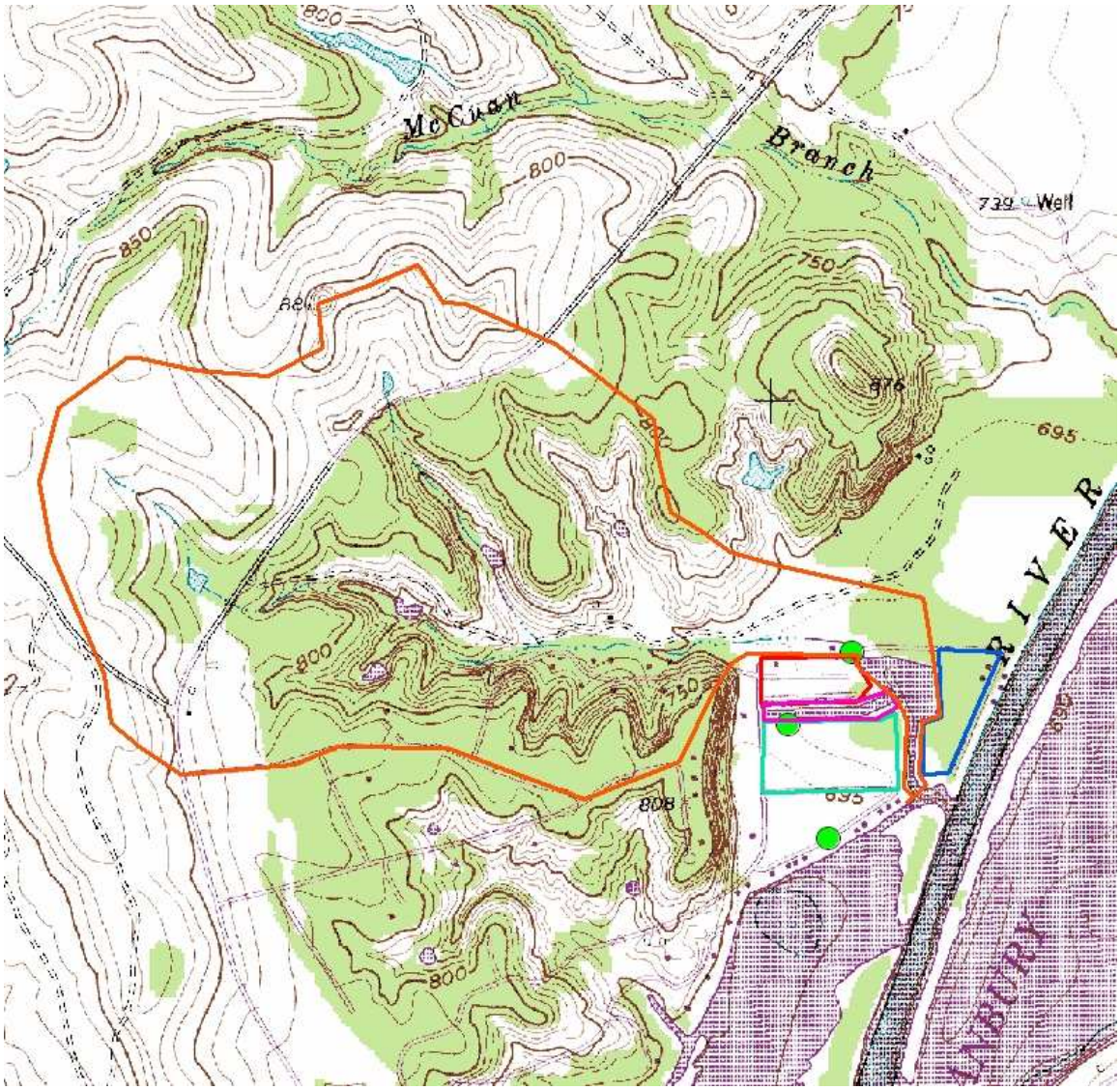
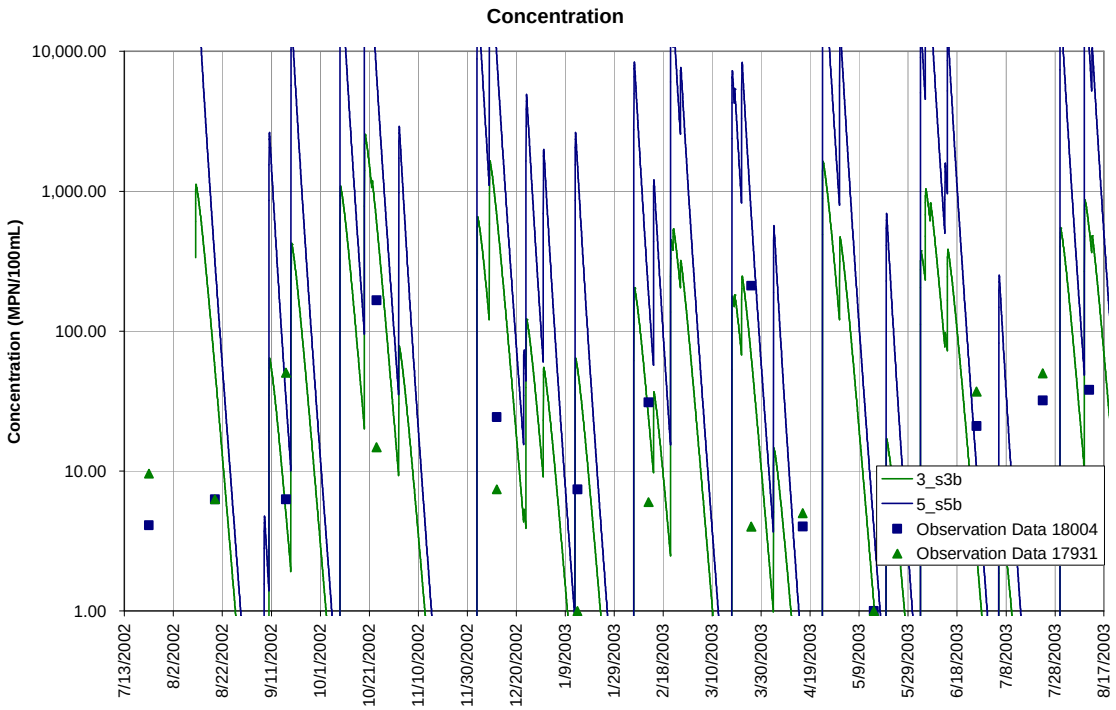


Figure E.2. Microwatershed Delineation for Rolling Hills Shores canals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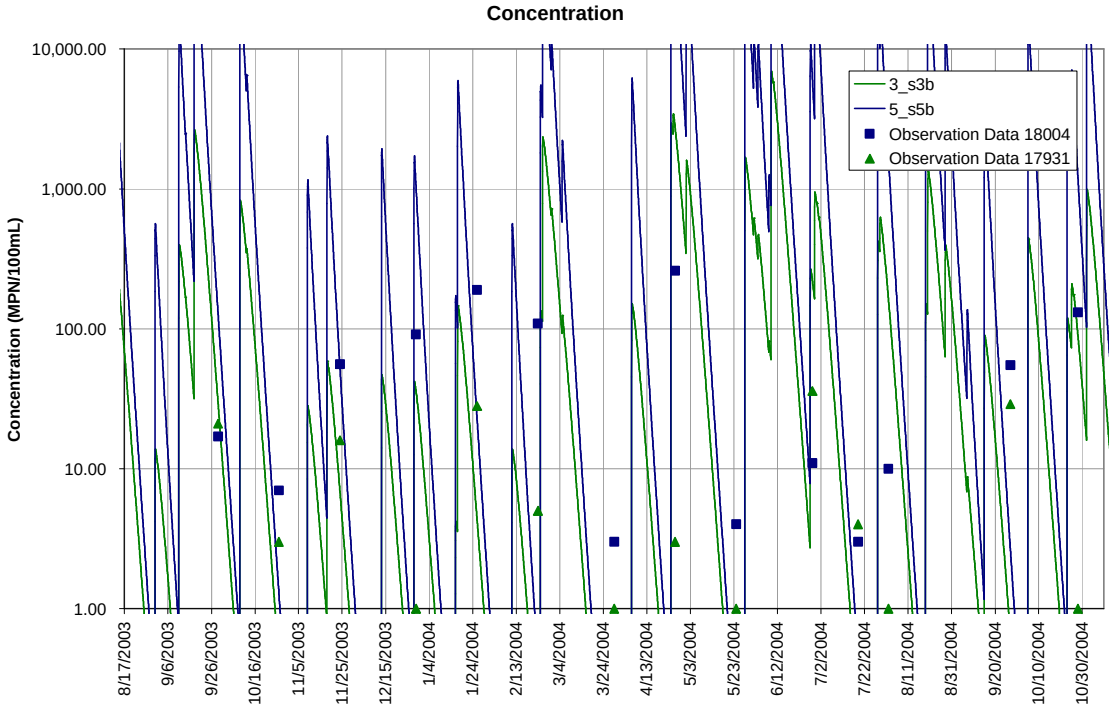
Observation Data 18004
Observation Data 17931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7/2/2004
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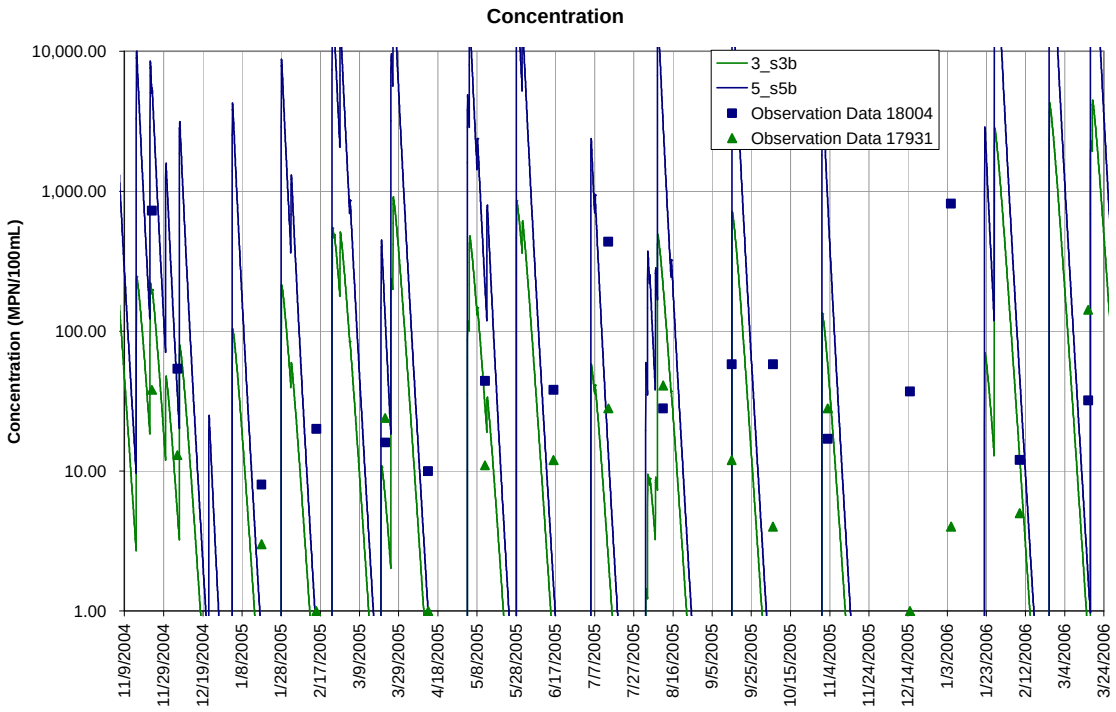
Observation Data 17931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3/9/2005
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4/18/2005
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5/28/2005
6/17/2005
7/7/2005
7/27/2005
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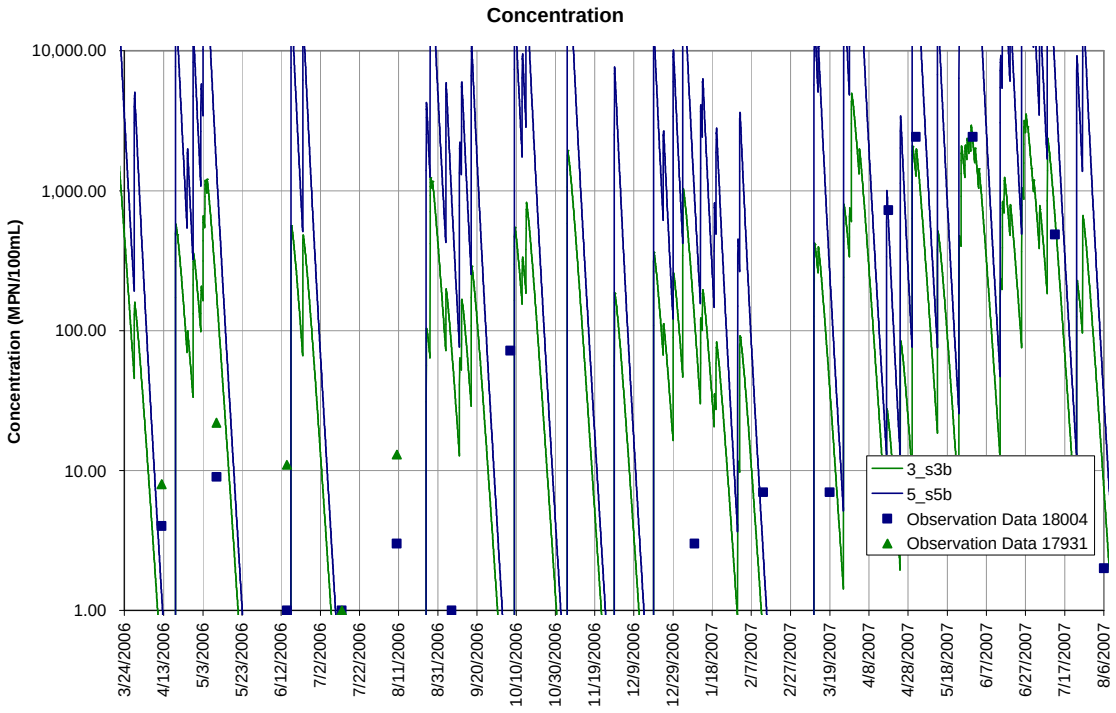
3/24/2006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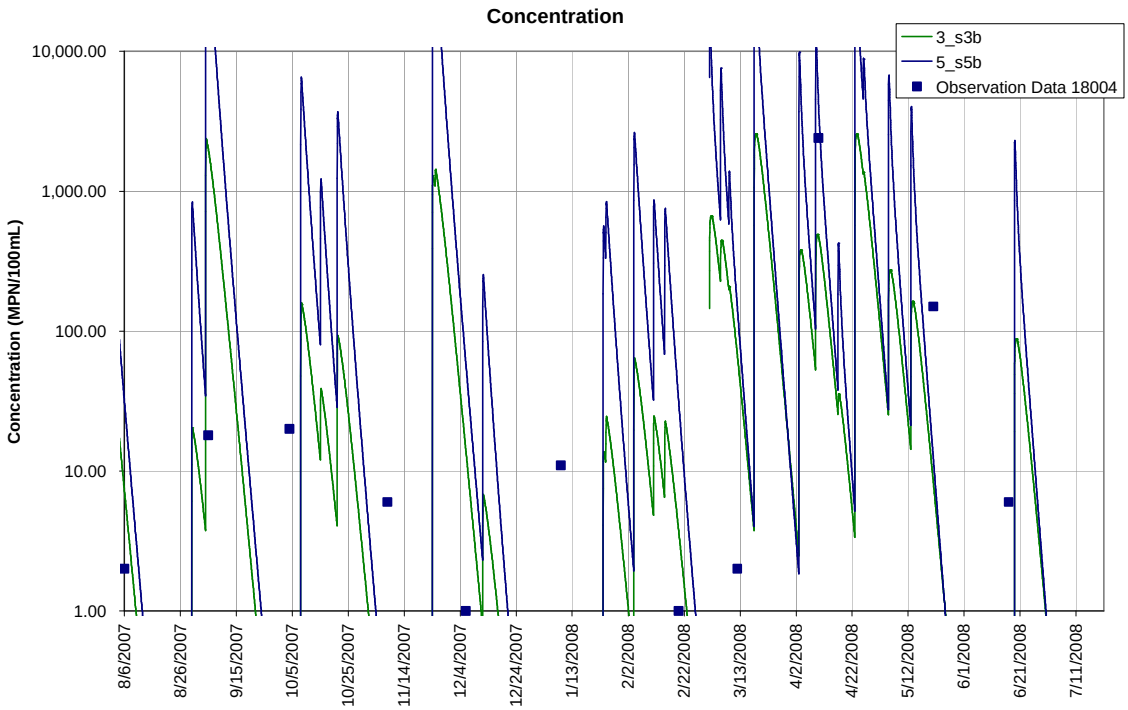


Figure E.3 Runoff model: Graphical Comparison of Observed vs. Modeled Bacteria Concentrations at Stations 18004 and 17931 located within the Rolling Hills Shores Canals

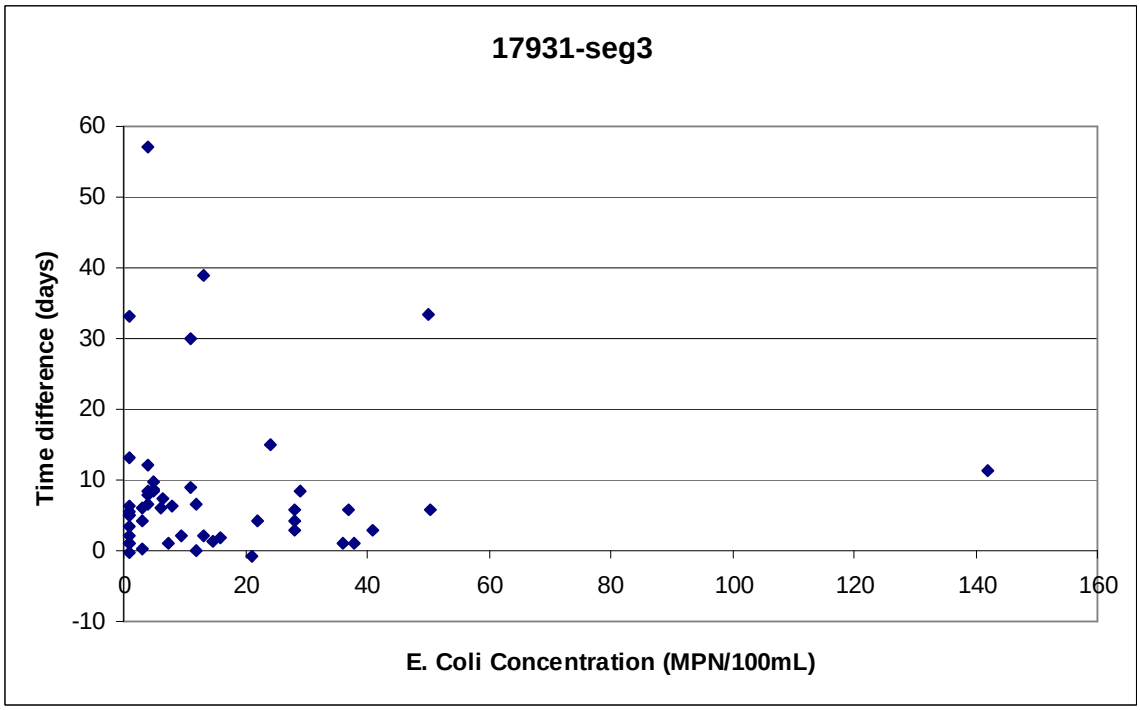


Figure E.4 Residual Plot for Station 17931 located within the Rolling Hills Shores Canals

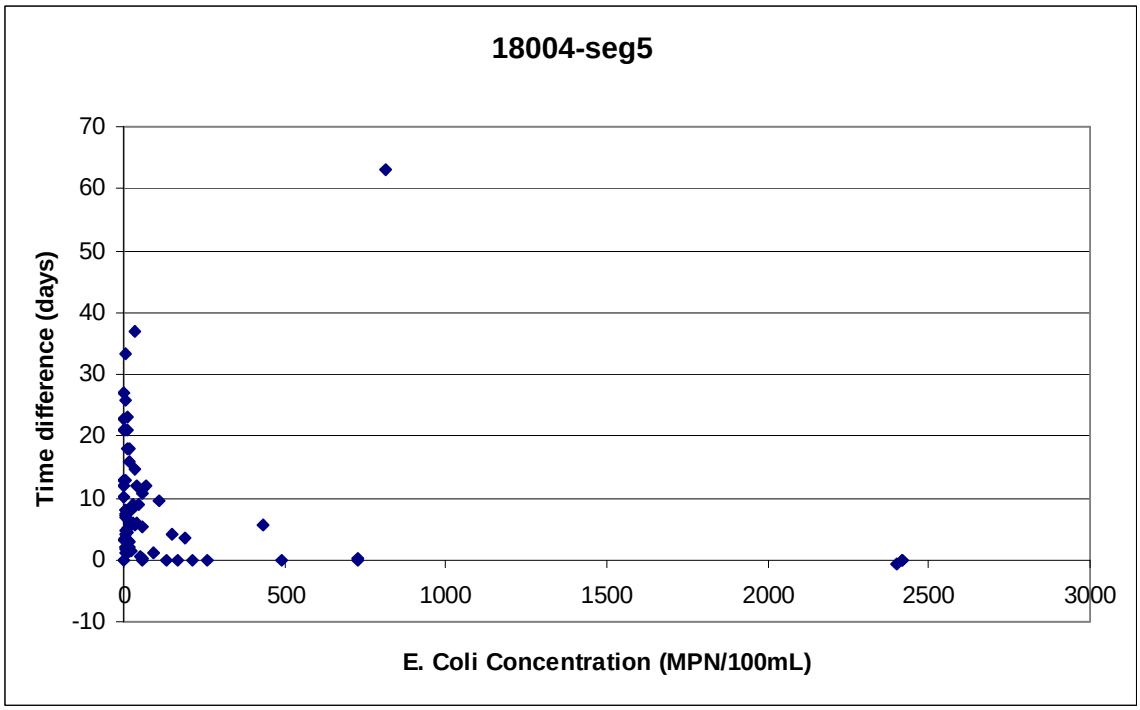


Figure E.5 Residual Plot for Station 18004 located within the Rolling Hills Shores Canals

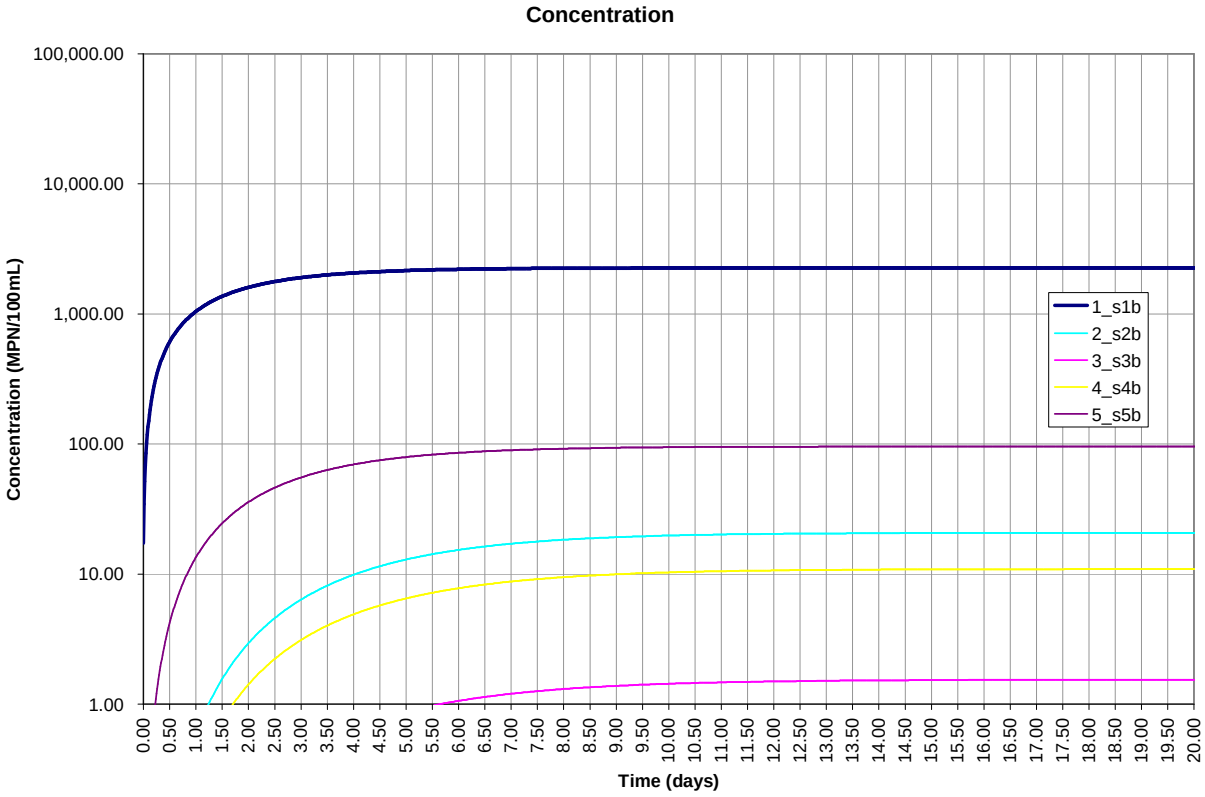


Figure E.6 Modeled Continuous Direct Discharge (septic) for Rolling Hills Shores

E.2.2 Arrowhead Shores

Model segmentation was conducted according to flow directions and canal geometry. The Arrowhead Shores canal system is divided into five segments as shown in Figure E.7. Mass balance using Equation E-1 is calculated for each segment in the spreadsheet model. The flow directions are: 1→2, 2→5, 3→4, 4→5, 5→lake. The microwatershed for this canal system is isolated to a small region immediately adjacent to the canal (Figure E.8).

Figure E.7 Canal Segmentation for Modeling Arrowhead Shores

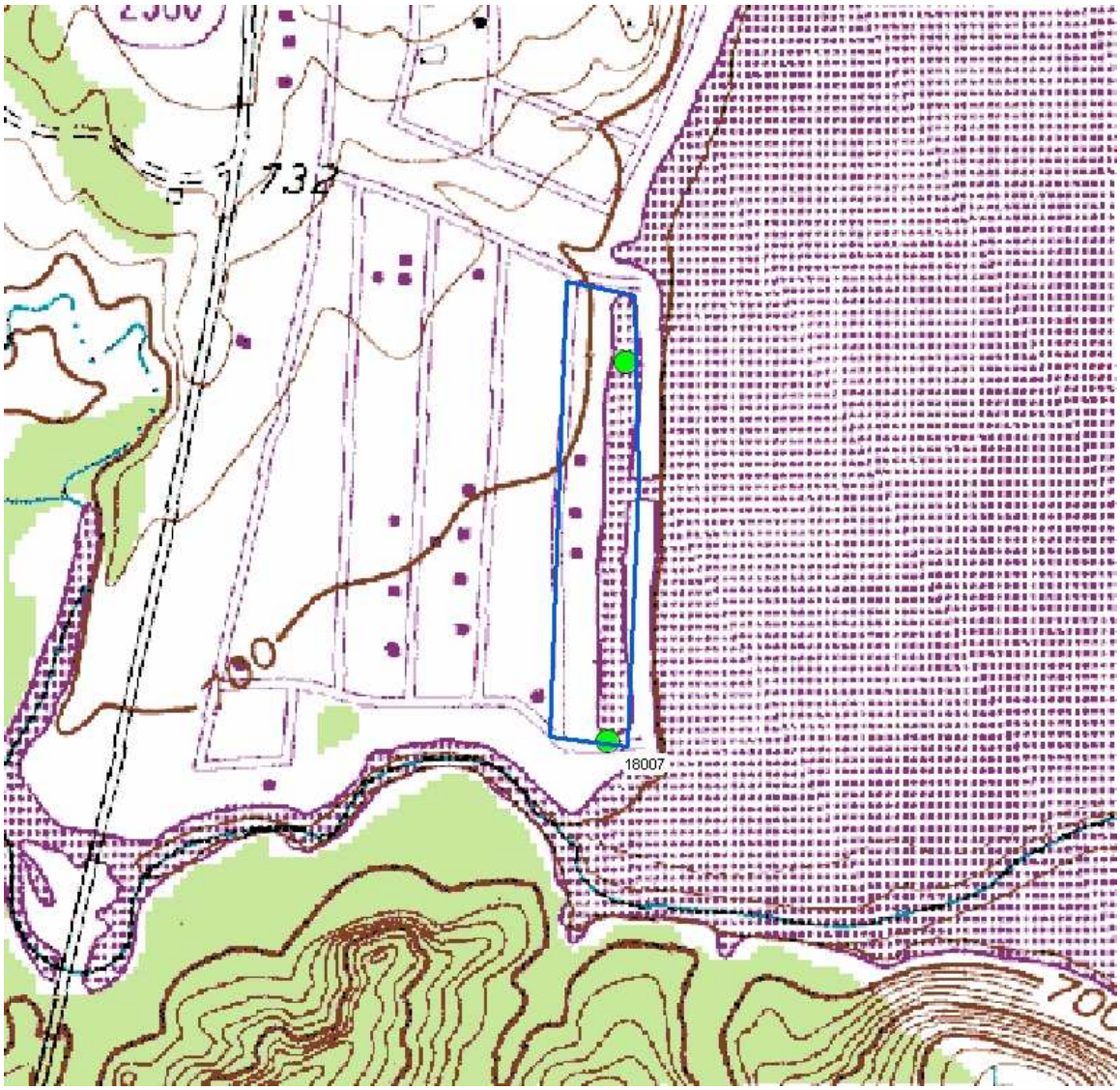
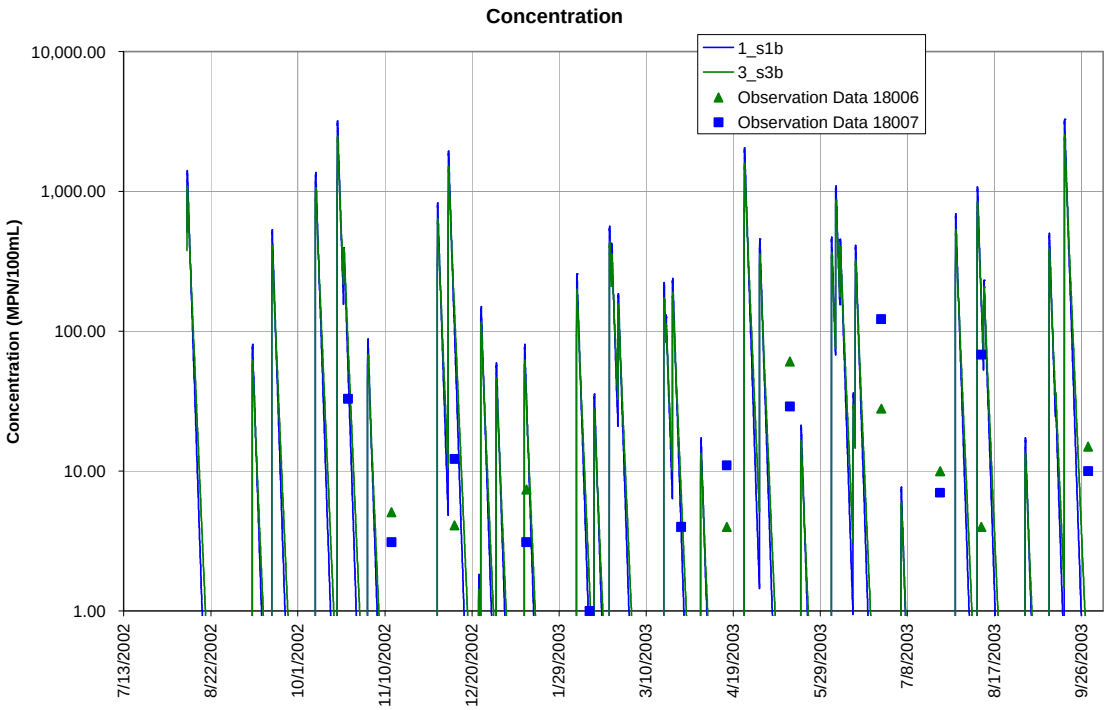


Figure E.8 Microwatershed Delineation for Arrowhead Shores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Observation Data 18007
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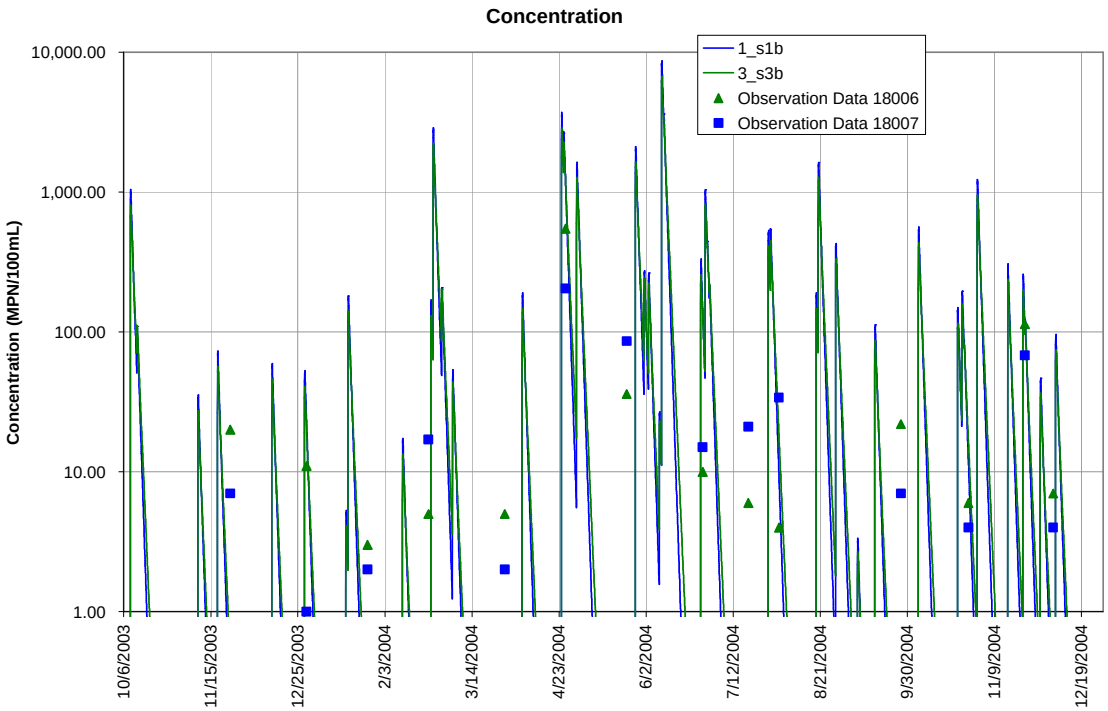
9/26/2003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3_s3b
Observation Data 18006
Observation Data 18007
Concentration (MPN/100mL)
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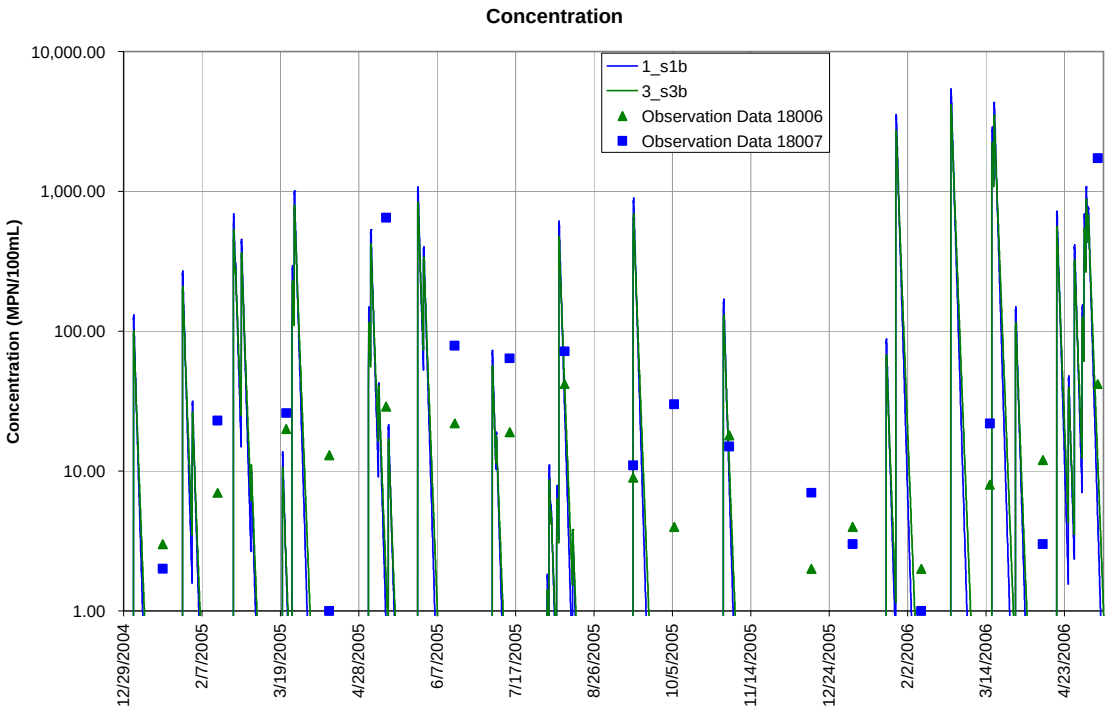
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4/28/2005
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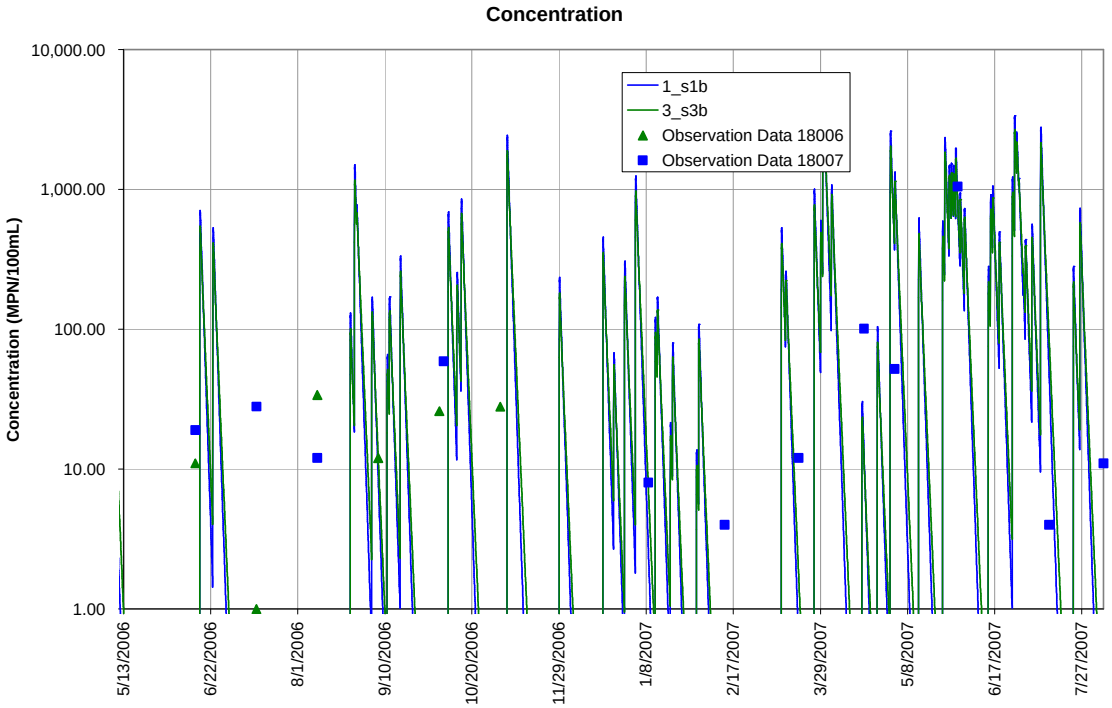
Concentration
Concentration (MPN/100mL)
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100.00
10.00
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1_s1b
3_s3b
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Observation Data 18007
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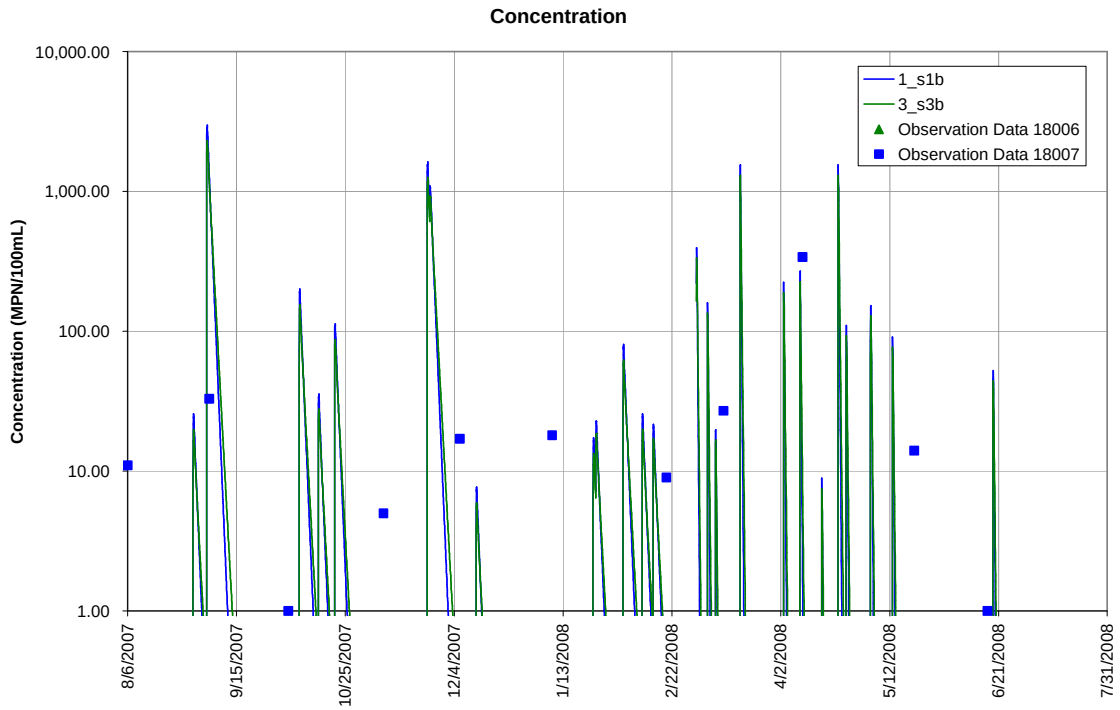


Figure E.9 Runoff model: Graphical Comparison of Observed vs. Modeled Bacteria Concentrations at Stations 18006 and 18007 located within the Arrowhead Shores Canals

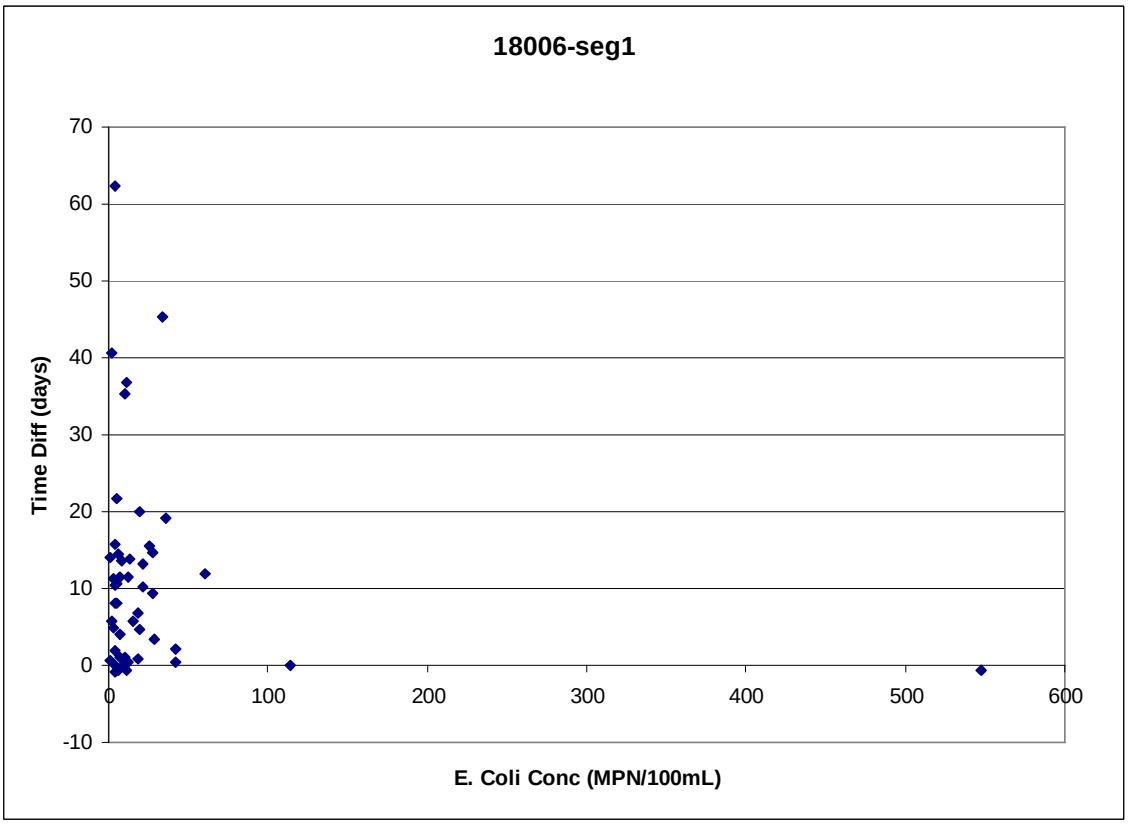


Figure E.10 Residual Plot for Station 18006 located within the Arrowhead Shores Canals

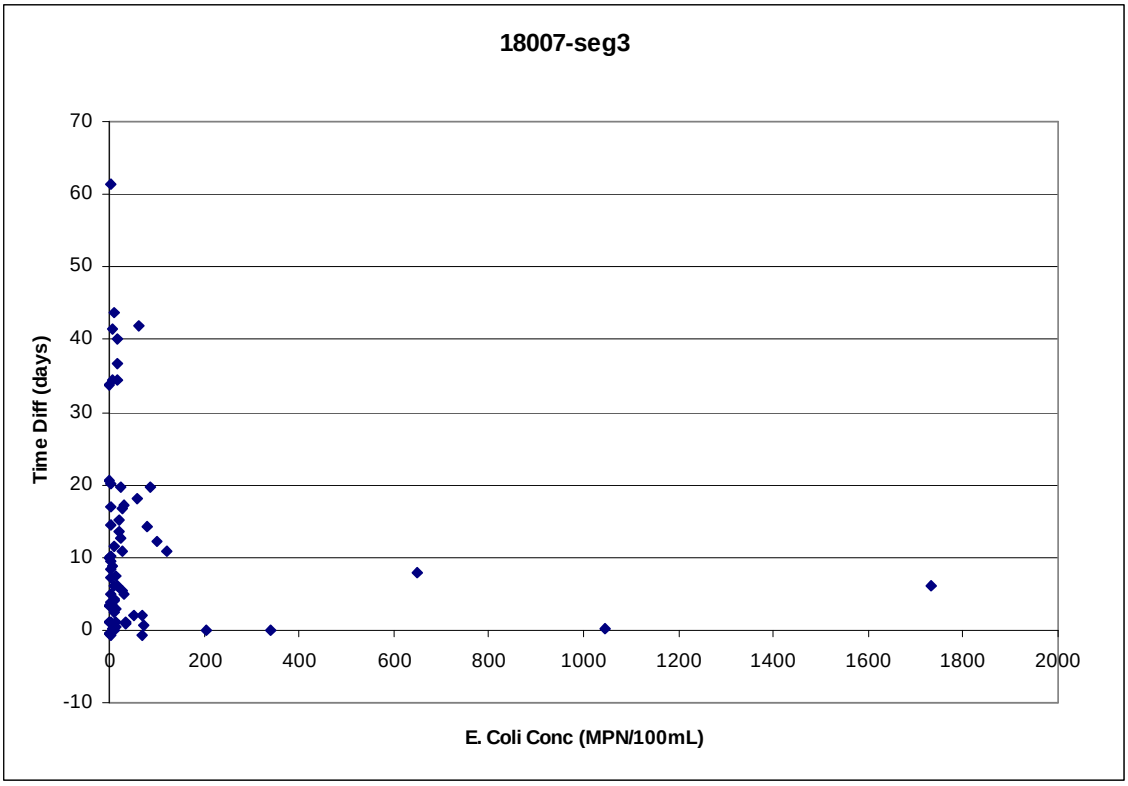


Figure E.11 Residual Plot for Station 18007 located within the Arrowhead Shores Canals

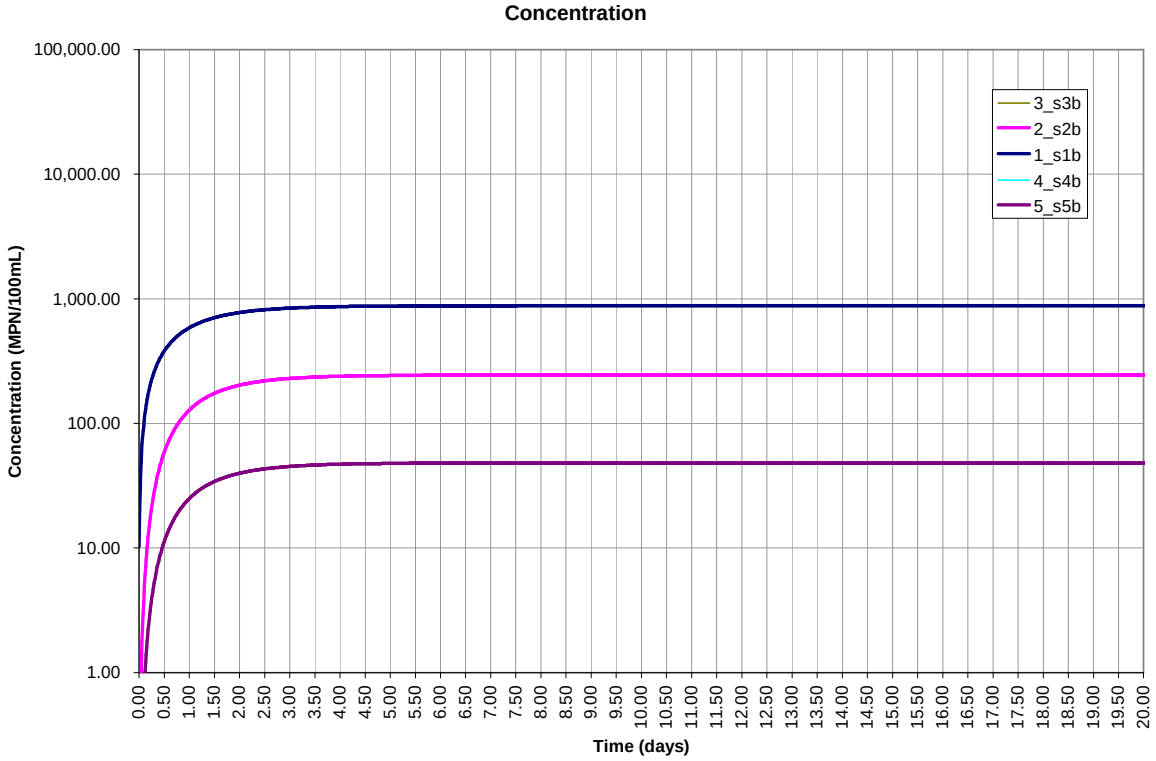


Figure E.12 Modeled Continuous Direct Discharge (septic) in Arrowhead Shores

E.2.3 Oak Trail Shores

Model segmentation was conducted according to flow directions and canal geometry. The Oak Trail Shores canal system is divided into five segments as shown in Figure E.13. Mass balance using Equation E-1 is calculated for each segment in the spreadsheet model. The flow directions are: 1→2, 2→5, 3→4, 4→5, 5→lake. Approximate dimensions and volumes of each segment are tabulated in Table E-1 for Oak Trail Shores.

Table E-1. Dimensions and Volumes for each segment in Oak Trail Shores

Segment	1	2	3	4	5
Length (m)	169.3	161.6	173.7	183.7	107.3
Width (m)	8.9	9.5	9.8	9.8	9.2
Depth (ft)	3.4	3.4	3.7	3.7	4.5
Depth (m)	1.04	1.04	1.13	1.13	1.37
Volume (m^3)	1561	1591	1920	2030	1354
Volume (L)	1561496	1590958	1919741	2030261	1353989

Figure E.13 Canal Segmentation for Modeling Oak Trail Shores

There are three micro-watersheds around the Oak Trail Shores canal system (Figure E.14), which are numbered as Watershed 1 (red polygon), 2 (yellow polygon) and 3 (green polygon). The respective areas for Watersheds 1, 2, and 3 are 110 acres, 76 acres and 58 acres.

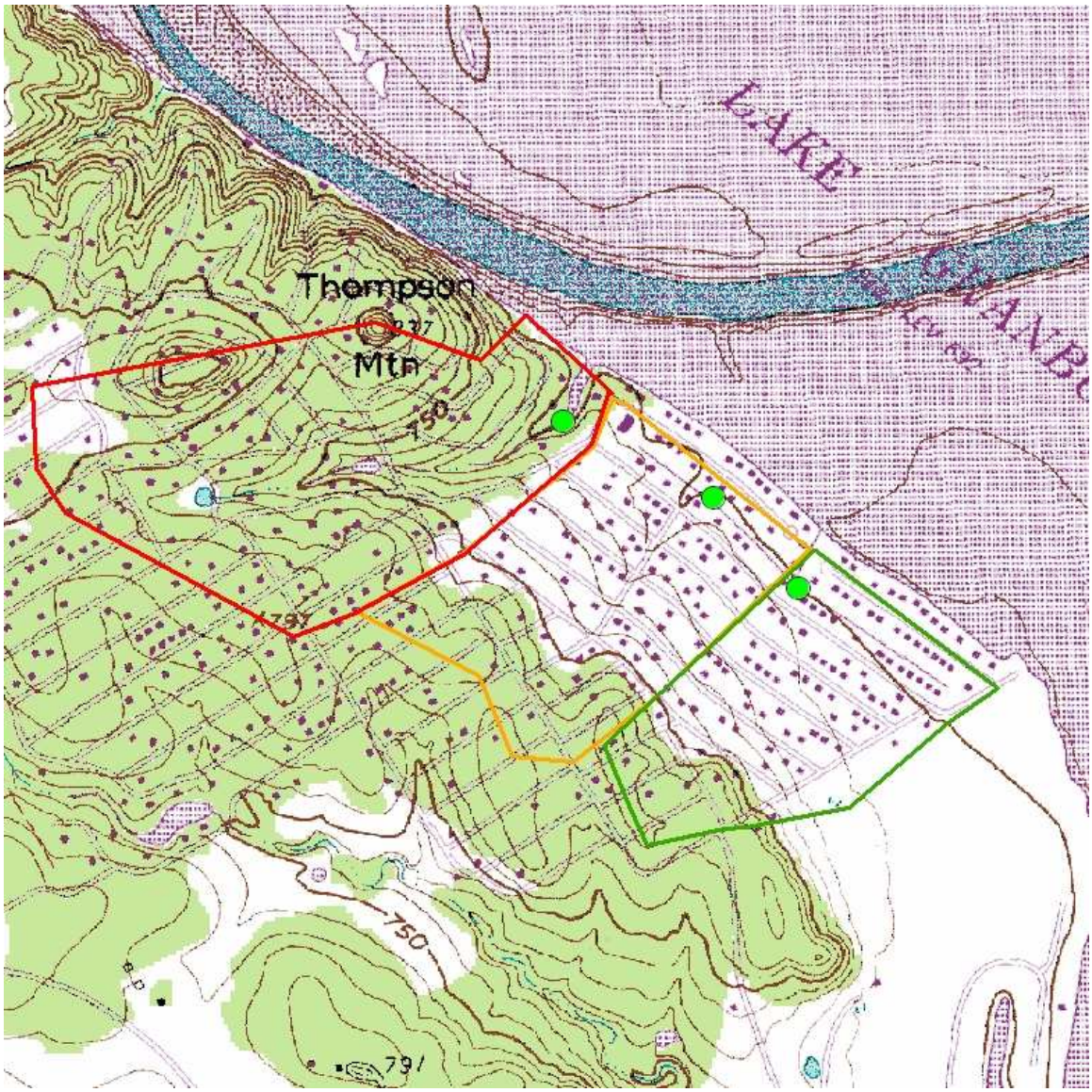
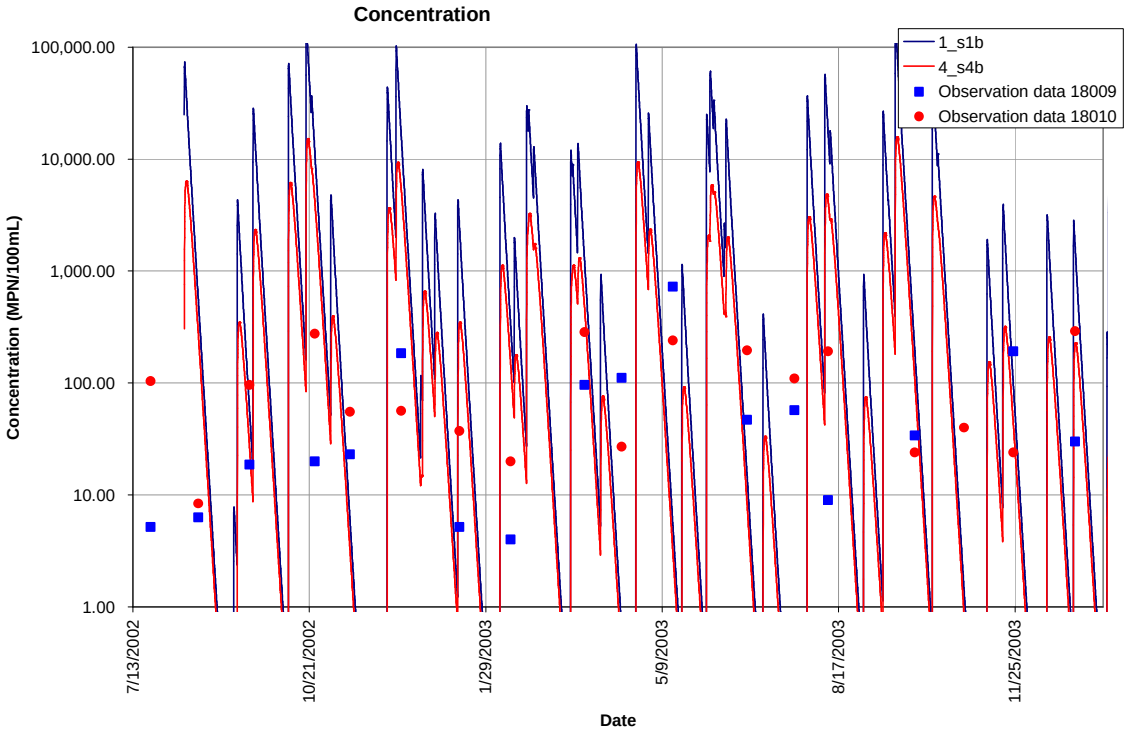


Figure E.14 Microwatershed Delineation for Oak Trail Shores

Residual plots of non-point source loads from Oak Trail Shores are shown in Figure E.19 and Figure E.20. The time difference between monitoring bacteria concentration at station 18009 and the model predicted bacteria level in segment 1 is illustrated in Figure E.15. The time difference between monitoring bacteria concentration at station 18010 and the model predicted bacteria level in segment 4 is also plotted in Figure E.15.

The plots are indicators of correspondence between model outputs and observed bacteria concentration. High bacteria concentration in the Oak Trail Shores area correspond to predicted rainfall-induced non-point source loadings (such as area-wide septic system malfunction and pets), while lower background bacterial levels were from other sources (potentially from septic failures or pets adjacent to the canal).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Observation data 18009
Observation data 18010
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100.00
10.00
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Concentration (MPN/100mL)
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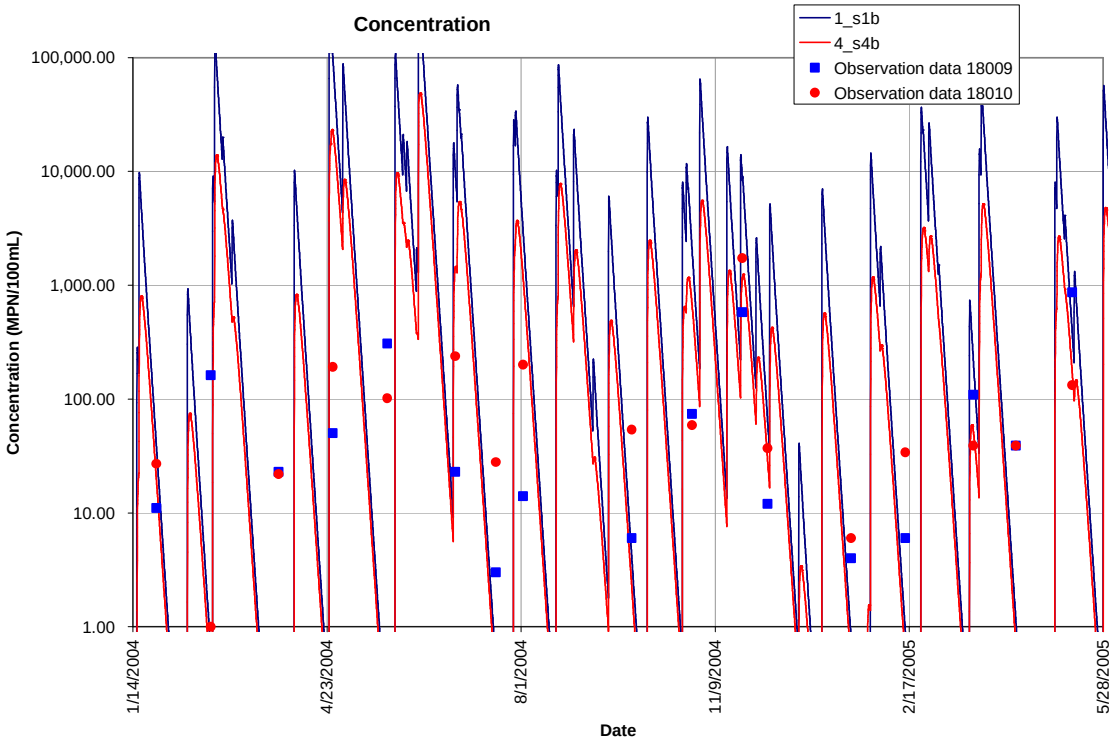
5/9/2003
8/17/2003
11/25/2003
Date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Observation data 18009
Observation data 18010
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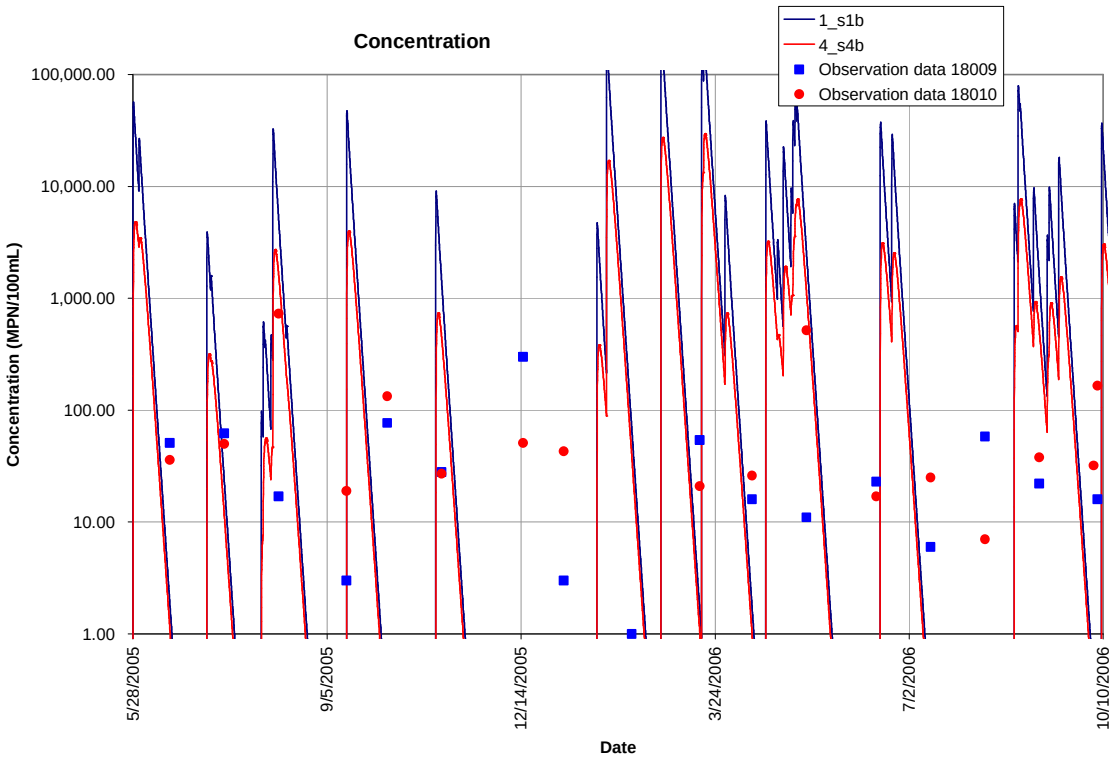
Date



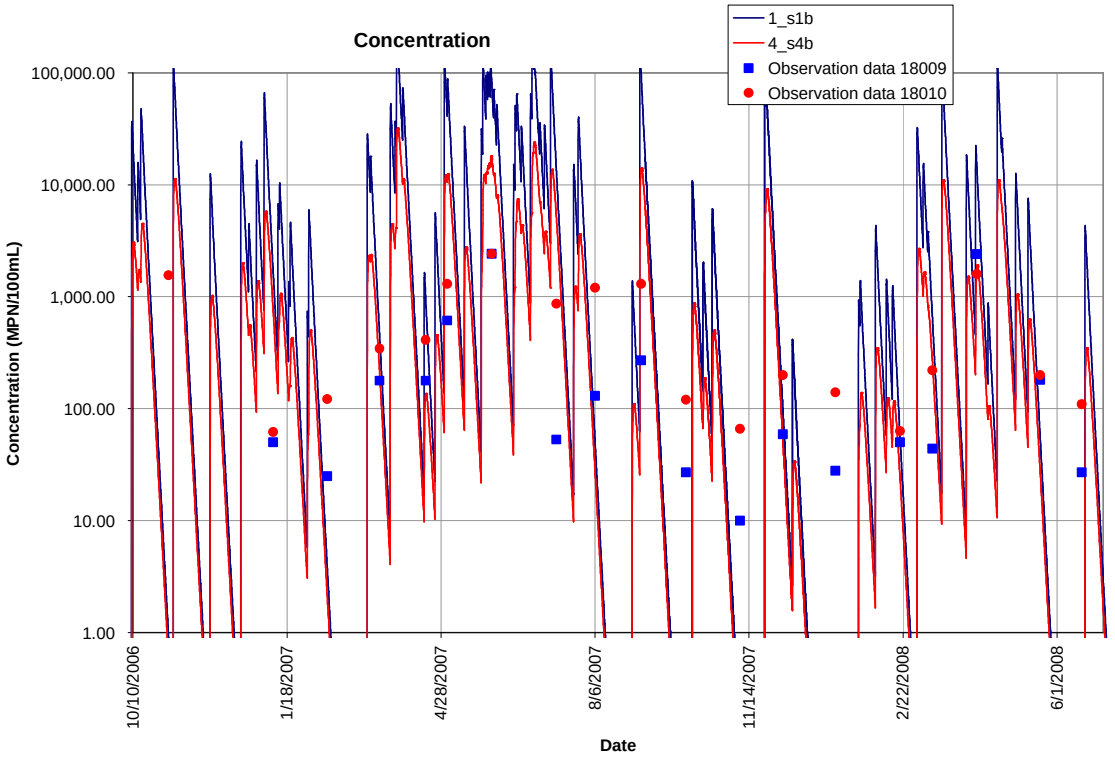


Figure E.15 Runoff Model: Graphical Comparison of Observed vs. Modeled Bacteria Concentrations at Stations 18009 and 18010 located within the Oak Trail Shores Canals

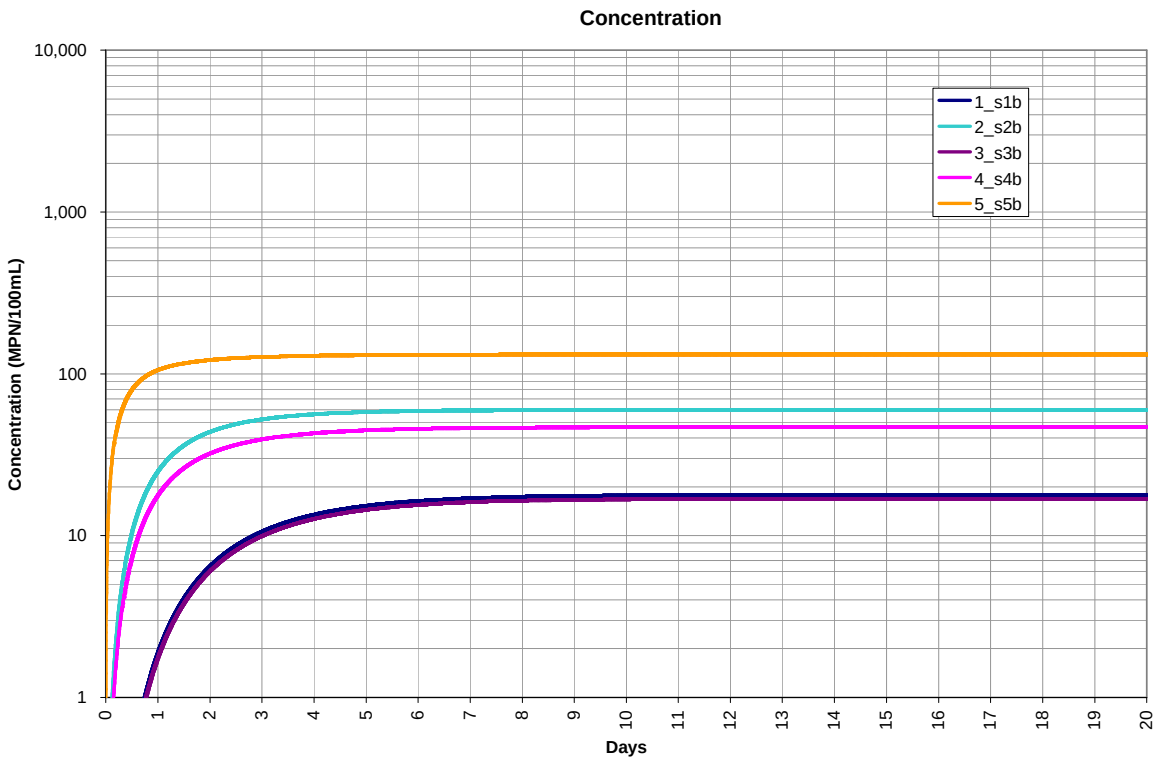


Figure E.16 Modeled Lake Boundary Condition for Oak Trail Shores Canals

The Oak Trail Shores canal was modeled with 1 residence discharging continuously to segment 1 (Figure E.17), the steady state concentration in segment 1 after 10-15 days is predicted at about 482,700 MPN/100mL. If the malfunction percentage is 10%, the steady state concentration in segment 1 is achieved in 10-15 days as 48,270 MPN/100mL.

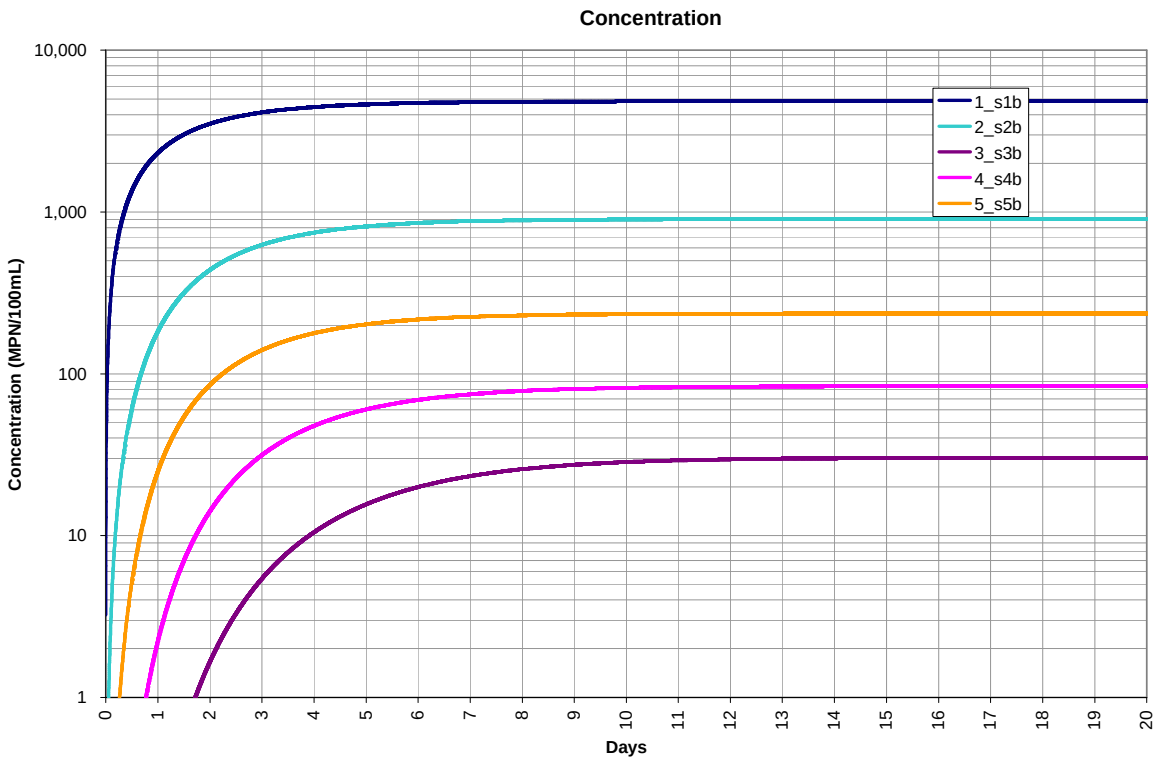


Figure E.17 Modeled Continuous Direct Discharge (septic) in Oak Trail Shores Canals

Another scenario was modeled to evaluate an intermittent point source. This scenario represents a short-duration septic system discharge into the cove water, as exhibited by a 33.3 gallon discharge of raw sewage into the canal. This load is consistent with 4 hours (or 1/6 of a day's effluent) for one residential household. A maximum concentration of approximately 500 MPN/100mL is predicted by the Oak Trail Shores model, with concentration staying above the stakeholder goal of 53 MPN/100ml for 3.5 days following the one-time discharge (Figure E.18).

Model results at this location indicate that a local concentration far in excess of the state water quality standards (geometric mean of 126 MPN/100mL) can be achieved with only one residence continuously discharging all sewage directly to the canal. In addition, short duration discharges from a single residence can result in locally-high bacteria concentrations.

Considering bacteria monitoring does not indicate high concentrations as high as those predicted by this scenario, a continuous and complete septic system malfunction is not likely a typical failure mode in this area. Rather, order-of-magnitude comparisons of data and model predictions indicate that a more typical failure mode is one that is intermittent (occurs only under certain high-stress conditions, e.g., during a large family gathering), a failure mode that is incomplete (only a small proportion of sewage is emitted) and/or a combination of intermittent/incomplete failures by one or more systems.

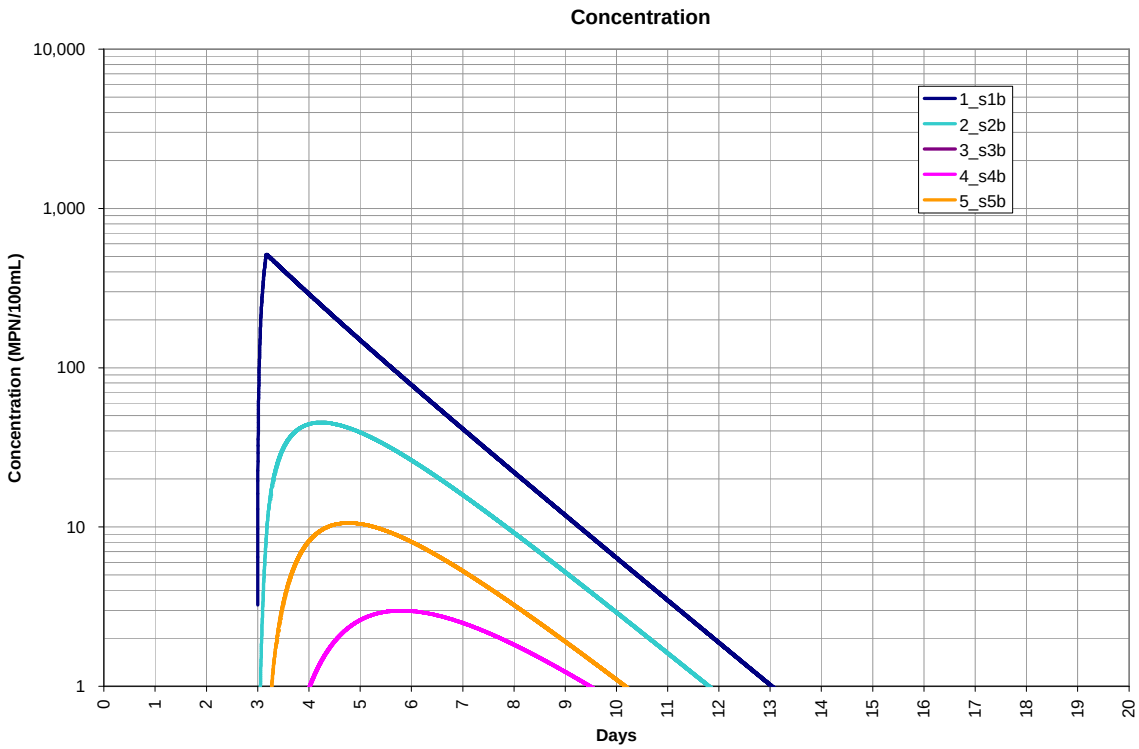


Figure E.18 Modeled Intermittent Direct Discharge (septic overload) in Oak Trail Shores Canals

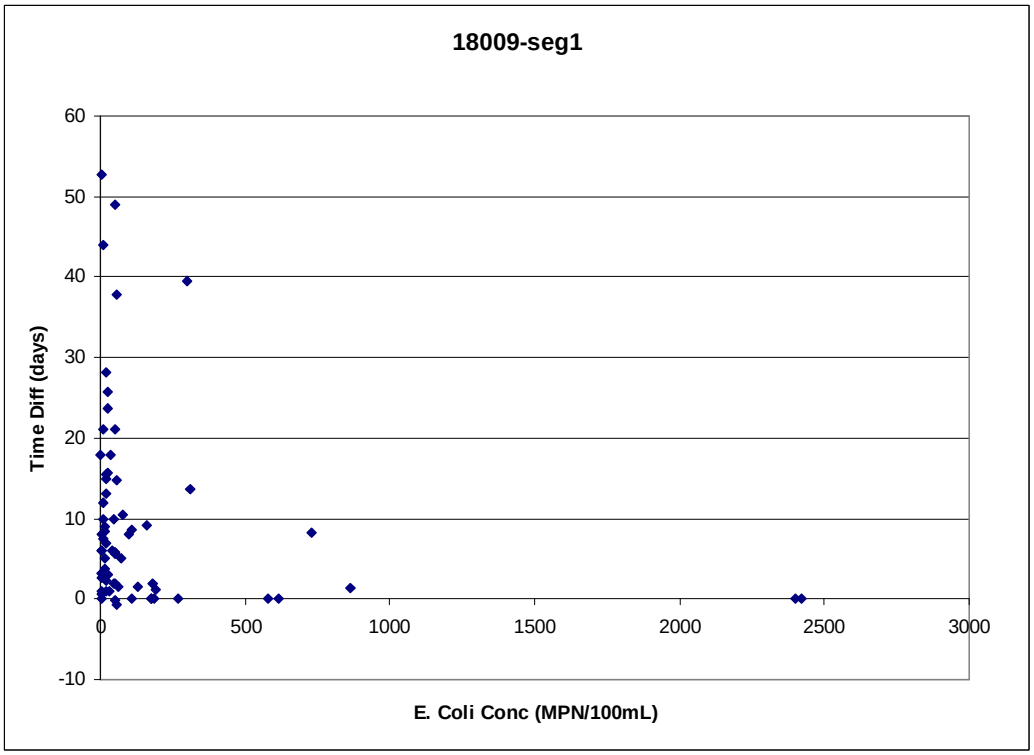


Figure E.19 Residual Plot for Station 18009 located within the Oak Trail Shores Canals

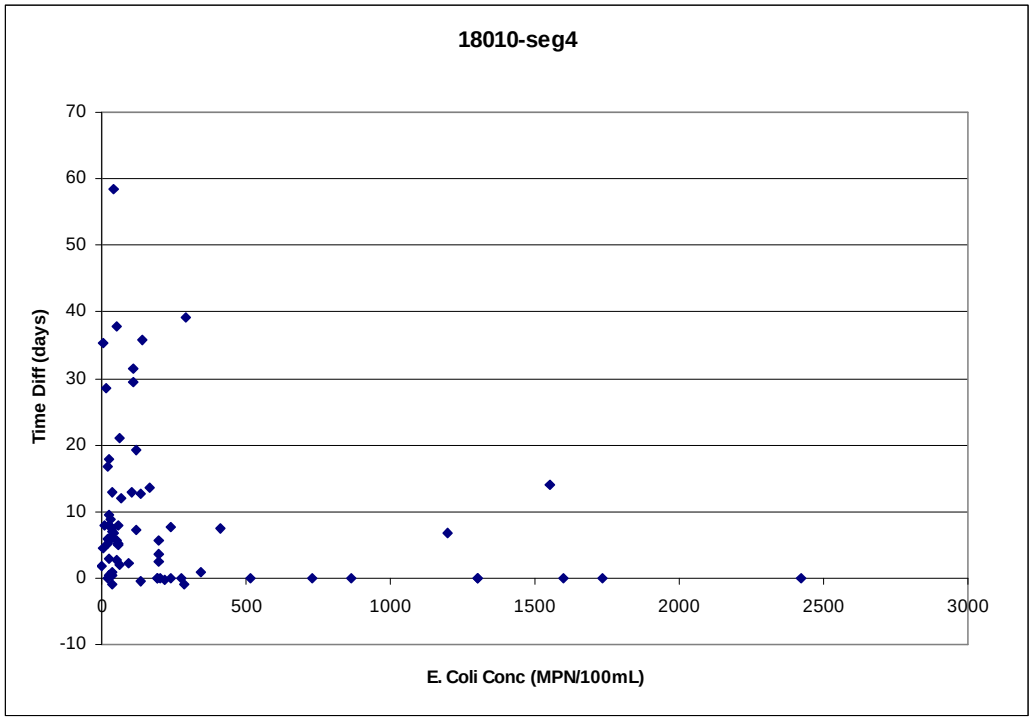


Figure E.20 Residual Plot for Station 18010 located within the Oak Trail Shores Canals

E.2.4 Sky Harbor

The Sky Harbor canal system was broken into 11 segments for the mass balance model. The flow direction is 1→4, 2→4. 3→4, 4→6, 5→6, 6→11, 7→11, 8→11, 9→11, 10→11, 11→lake. Mass balance using Equation E-1 is calculated for each segment in the spreadsheet model. Approximate dimensions and volumes of each segment are provided in Table E-2.

Table E-2. Dimensions and Volumes for each segment in Sky Harbor

Segment	1	2	3	4	5	6
Length (m)	223.0	96.3	245.0	292.0	130.0	389.0
Width (m)	6.1	12.6	13.5	19.6	42.0	39.0
Depth (ft)	4.5	7.3	6.7	8.3	9.0	9.0
Depth (m)	1.37	2.23	2.04	2.53	2.74	2.74
Volume (m3)	1,865.79	2,699.82	6,754.44	14,478.78	14,977.87	41,617.09
Volume (L)	1,865,787	2,699,819	6,754,444	14,478,780	14,977,872	41,617,087
Segment	**7**	**8**	**9**	**10**	**11**	
Length (m)	187.0	251.5	232.0	305.4	320.0	
Width (m)	17.6	20.1	71.5	16.9	62.0	
Depth (ft)	5.3	7.0	9.8	10.9	11.0	
Depth (m)	1.62	2.13	2.99	3.32	3.35	
Volume (m3)	5,316.74	10,785.67	49,549.02	17,147.36	66,519.55	
Volume (L)	5,316,736	10,785,668	49,549,020	17,147,357	66,519,552	

Figure E.21 Canal Segmentation for Modeling Sky Harbor

There are several small micro-watersheds near canal segments 5, 7, 8, and 9 and larger micro-watersheds for the other canals.

High bacteria concentration correspond to predicted rainfall-induced non-point source loadings. This is expected since these canals are influenced by larger watersheds

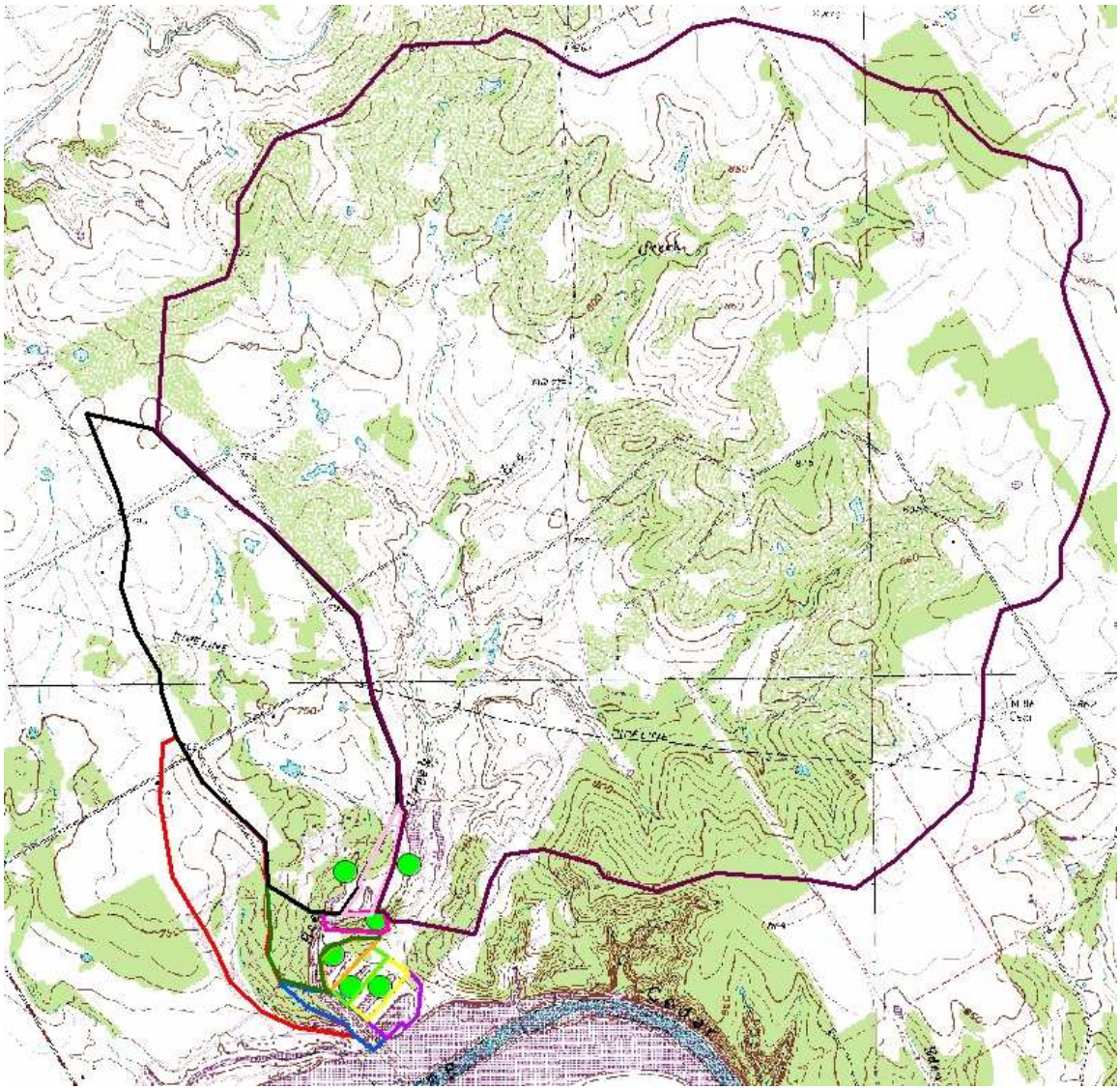
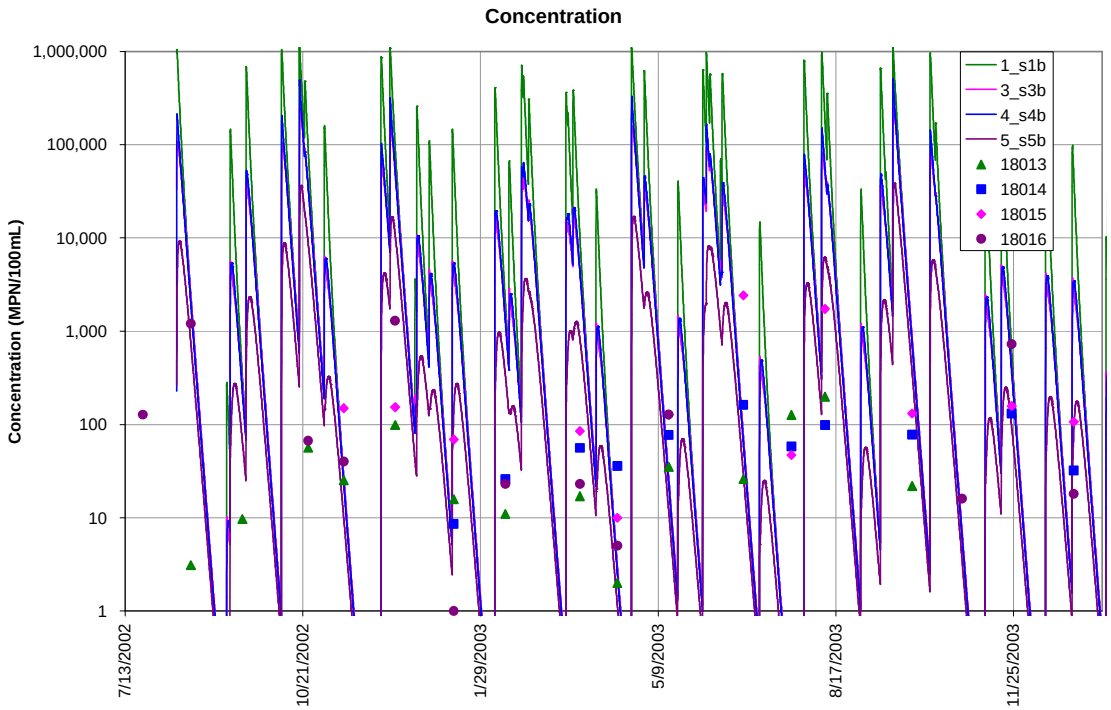


Figure E.22 Microwatershed Delineation for Sky Harbor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1,000
100
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5/9/2003
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11/25/2003
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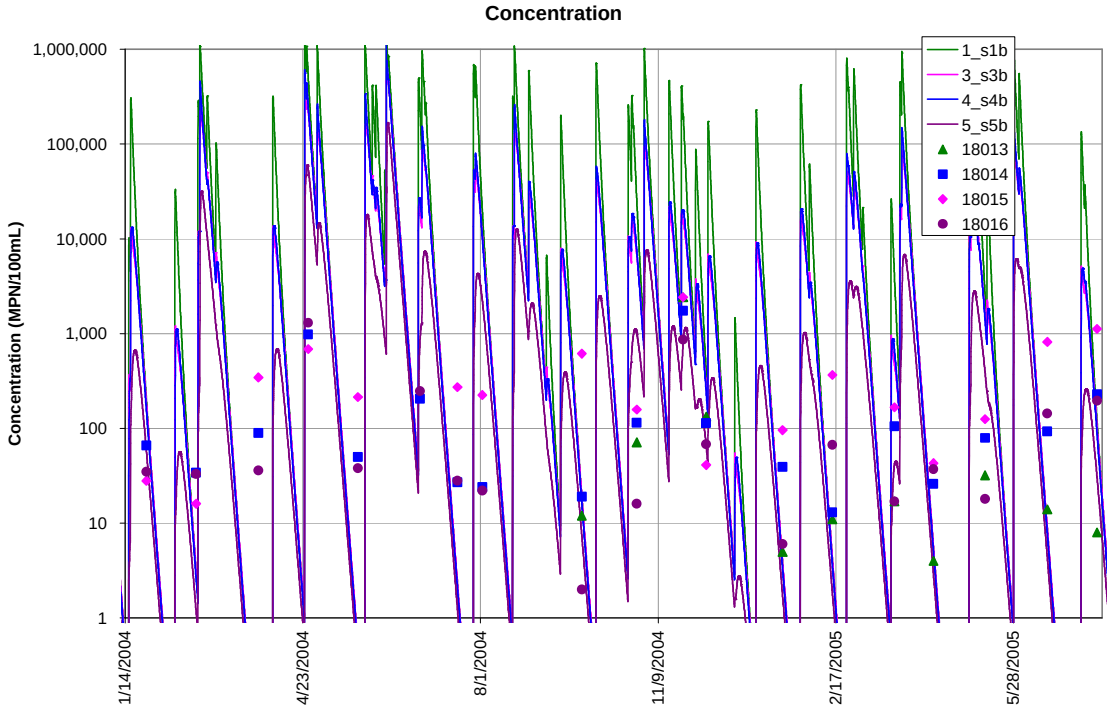
4_s4b
5_s5b
18013
18014
18015
18016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Concentration (MPN/100mL)
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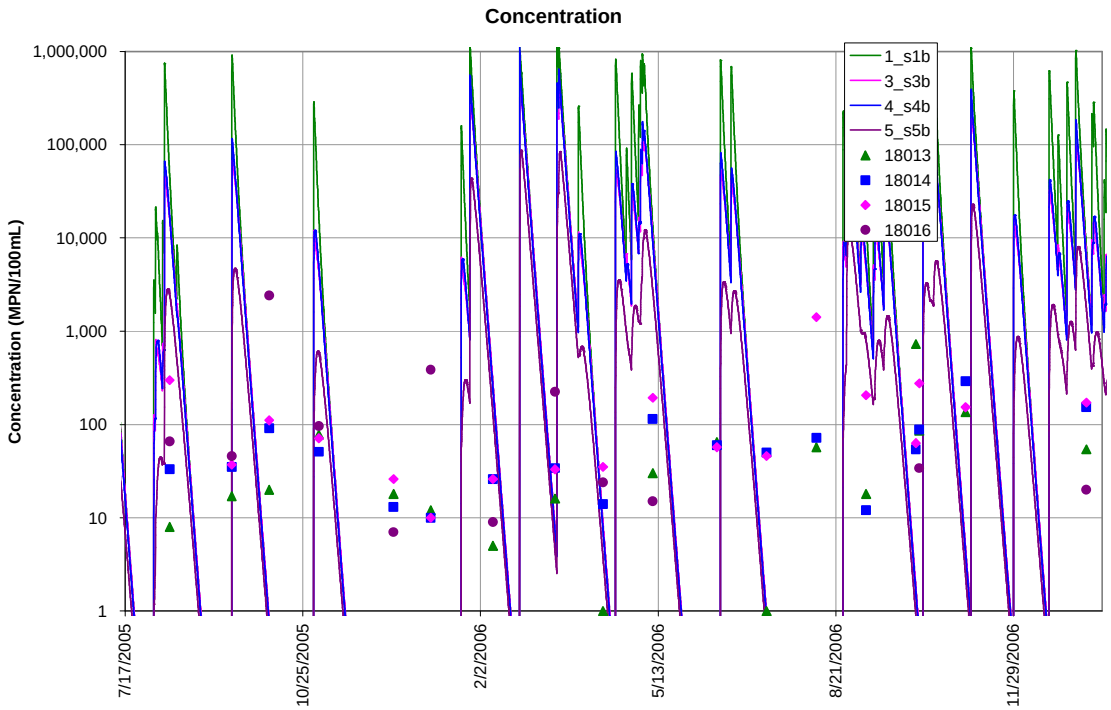
18013
18014
18015
18016



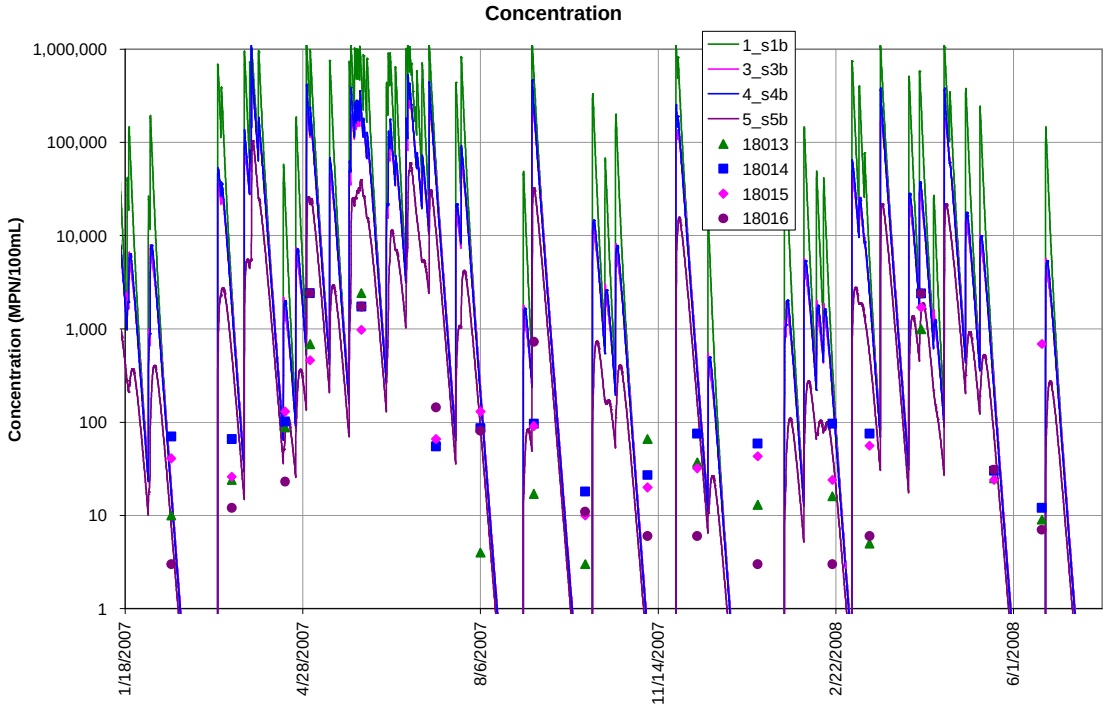


Figure E.23 Graphical Comparison of Observed vs. Modeled Bacteria Concentrations at Stations 18013, 18014, 18015, and 18016 located within the Sky Harbor Canals

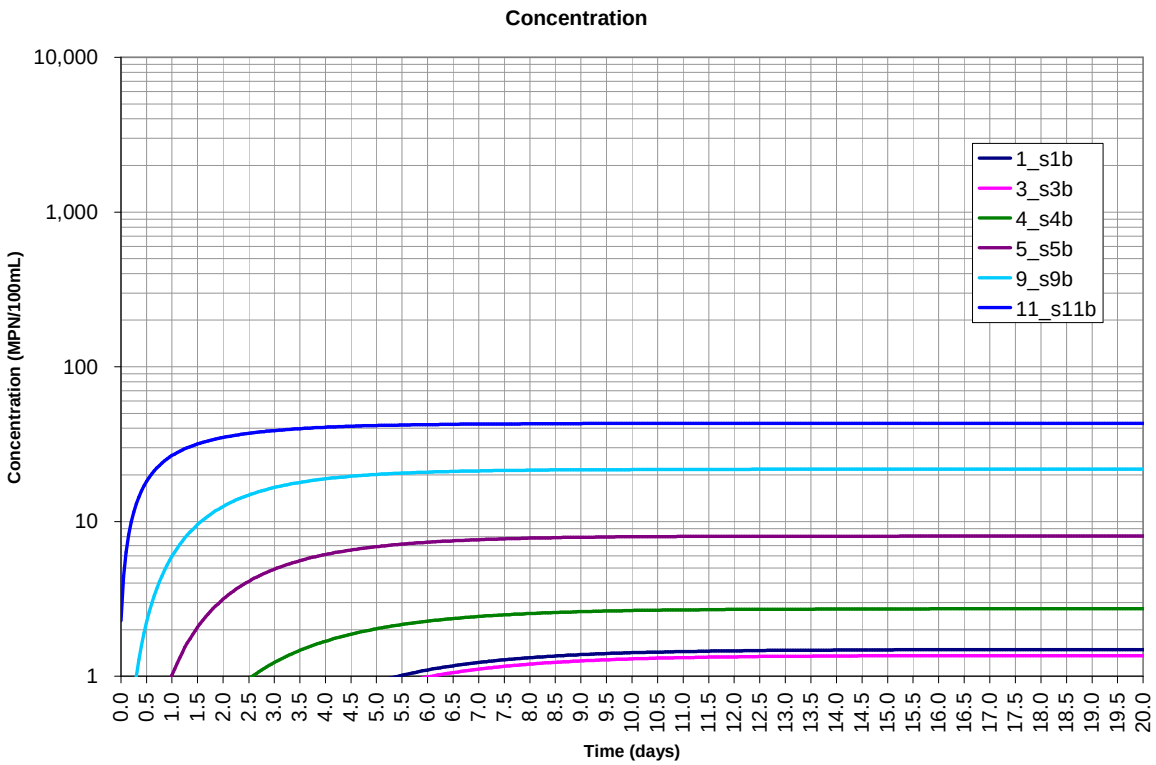


Figure E.24 Modeled Lake Boundary Condition for the Sky Harbor Canals

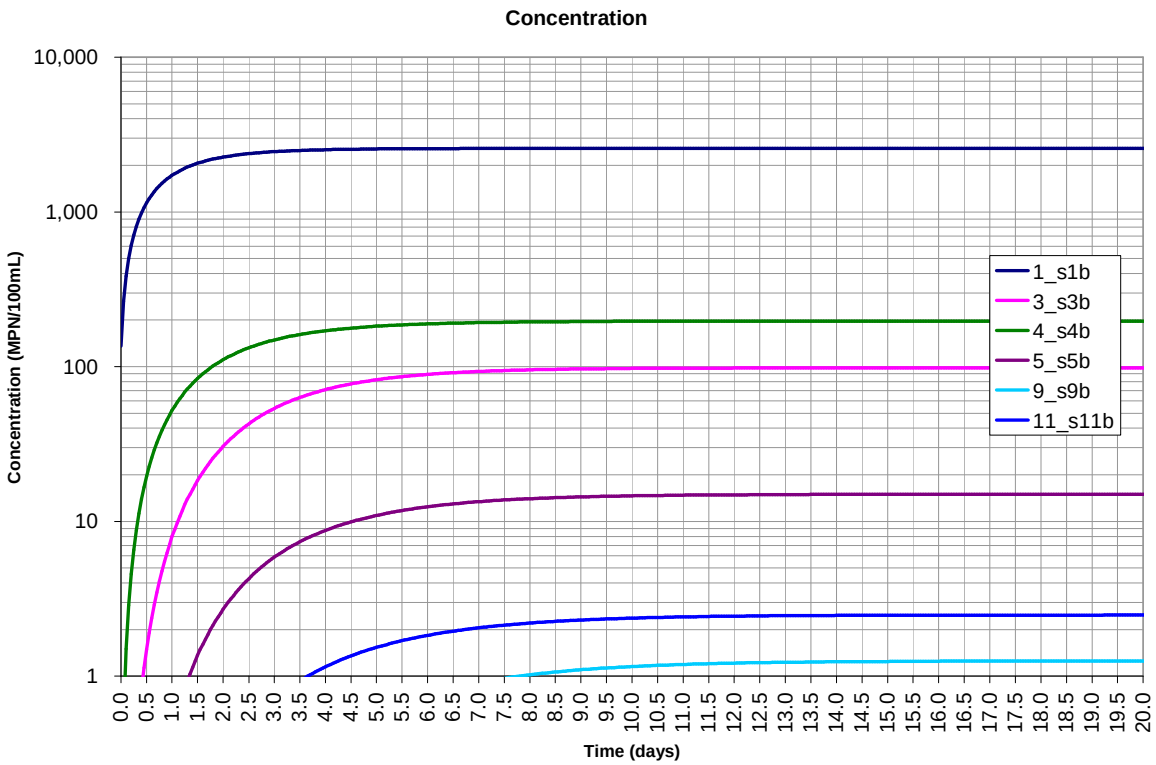


Figure E.25 Modeled Continuous Direct Discharge (septic) in the Sky Harbor Canals

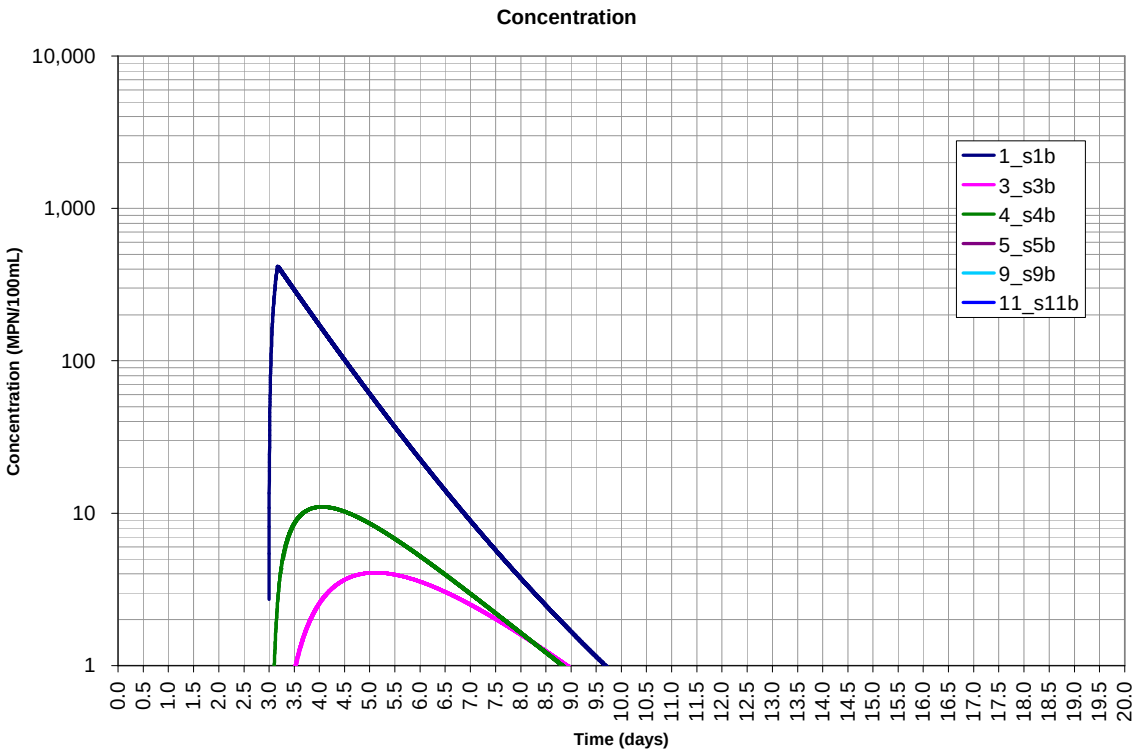


Figure E.26 Modeled Intermittent Direct Discharge (septic overload) in the Sky Harbor Canals

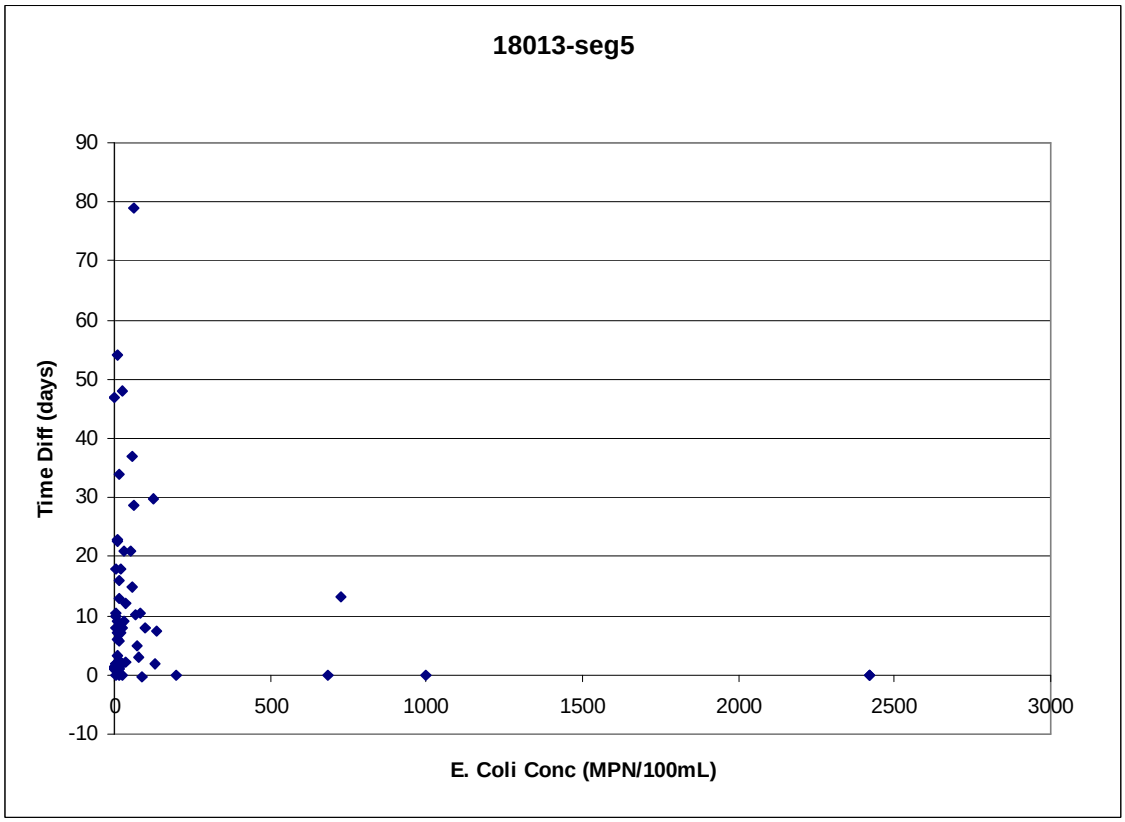


Figure E.27 Residual Plot for Station 18013 located within the Sky Harbor Canals

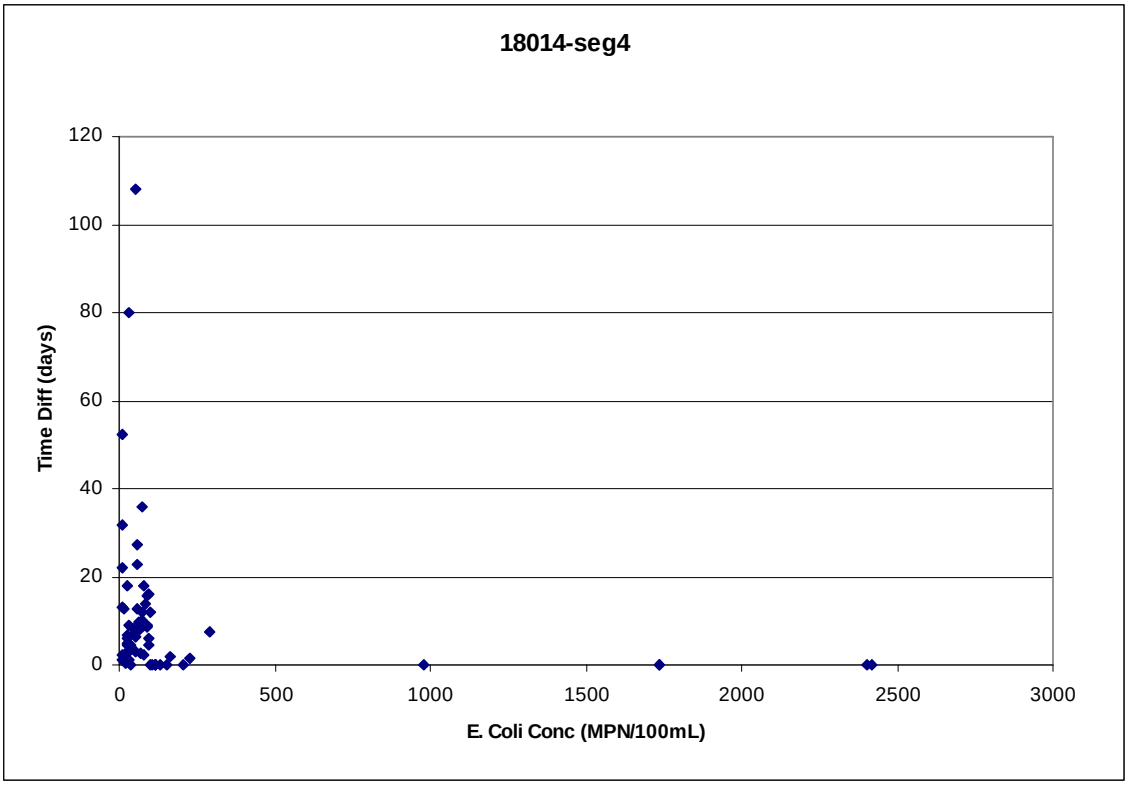


Figure E.28 Residual Plot for Station 18014 located within the Sky Harbor Canals

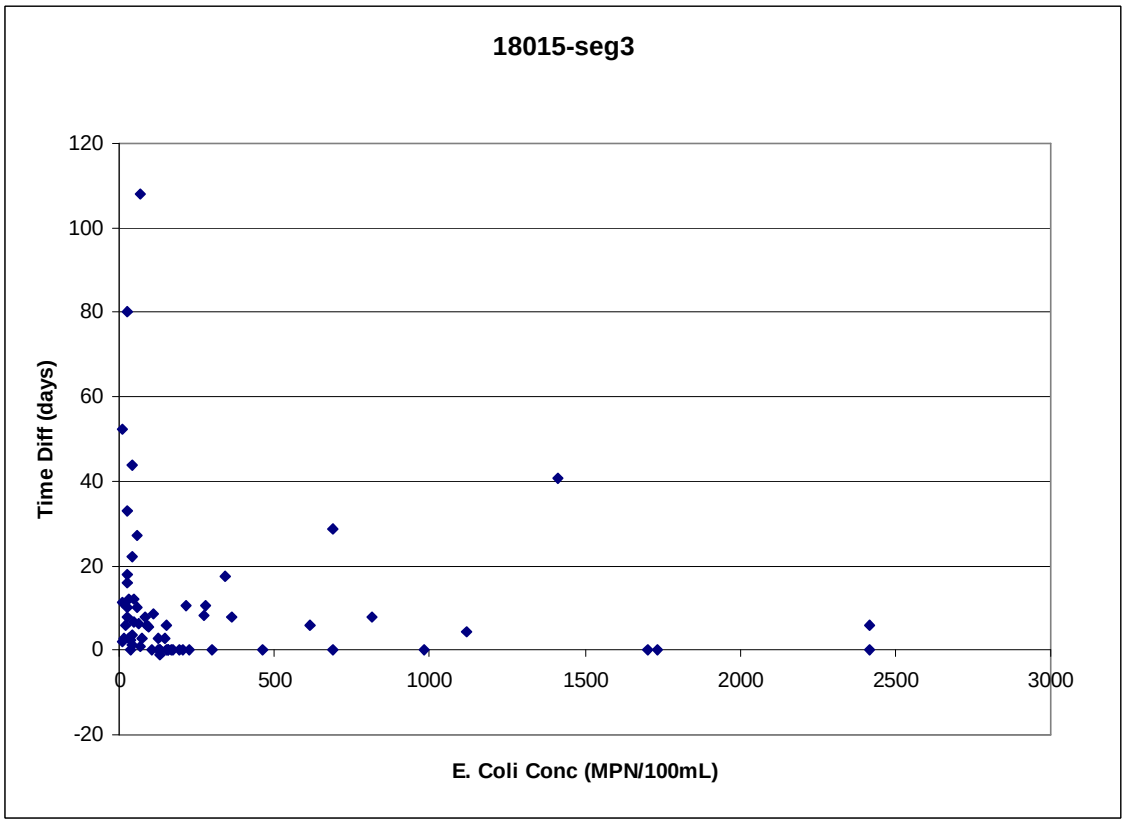


Figure E.29 Residual Plot for Station 18015 located within the Sky Harbor Canals

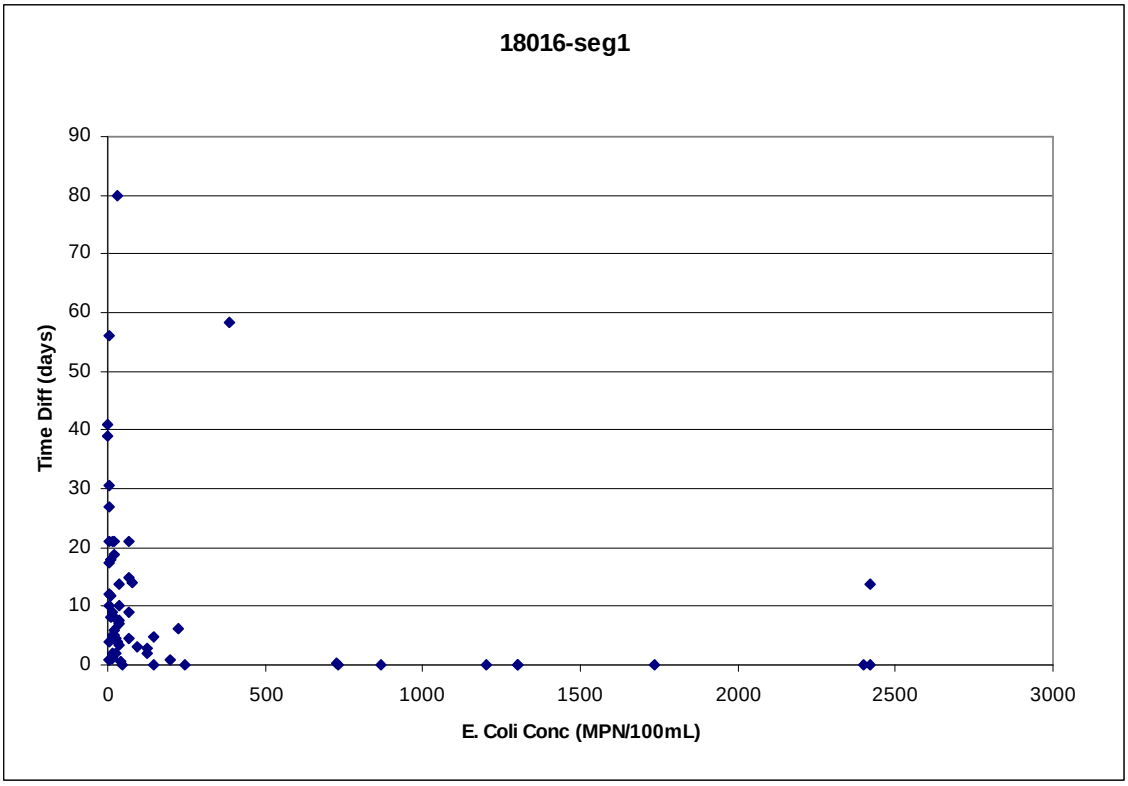


Figure E.30 Residual Plot for Station 18016 located within the Sky Harbor Canals

E.2.5 Nassau Bay II

Model segmentation was conducted according to flow directions and canal geometry. The Nassau Bay II canal that was modeled is divided into three segments as shown in Figure E.31. Mass balance using Equation E-1 is calculated for each segment in the spreadsheet model. The flow directions are: 1→2, 2→3, 3→lake. The contributing microwatershed (Figure E.32) is very localized to the neighboring residences

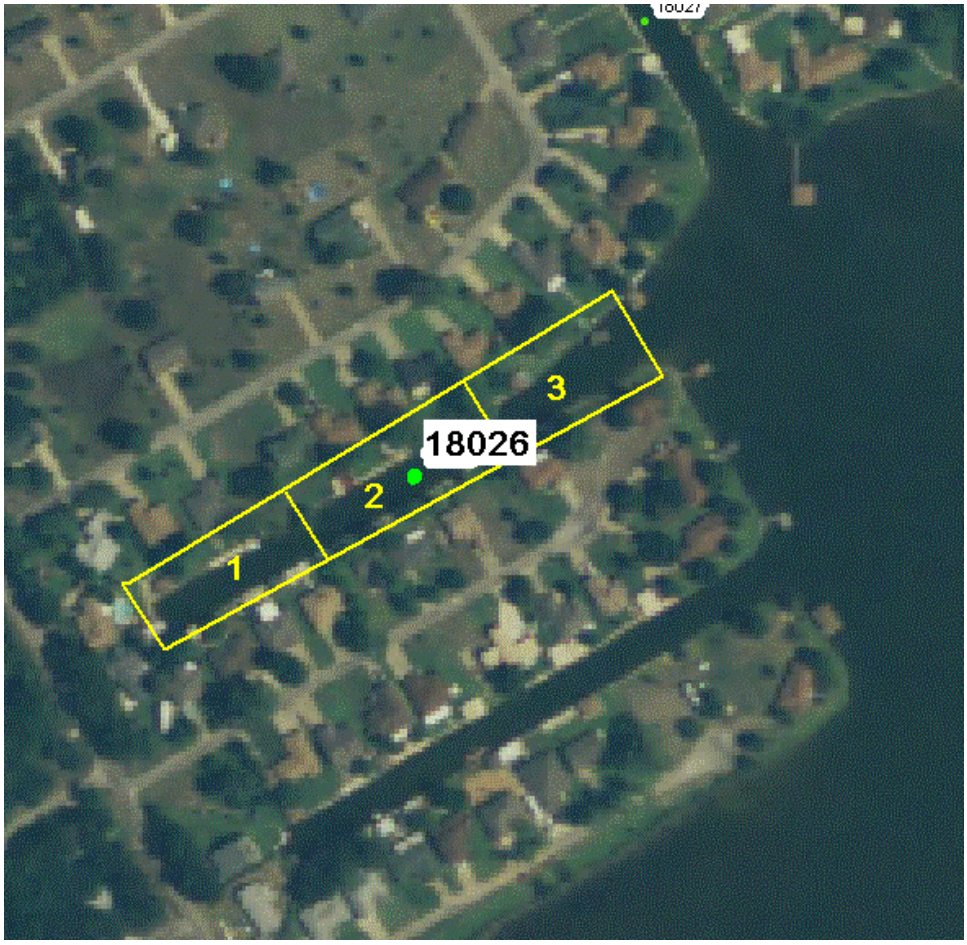


Figure E.31 Canal Segmentation for Modeling Nassau Bay II

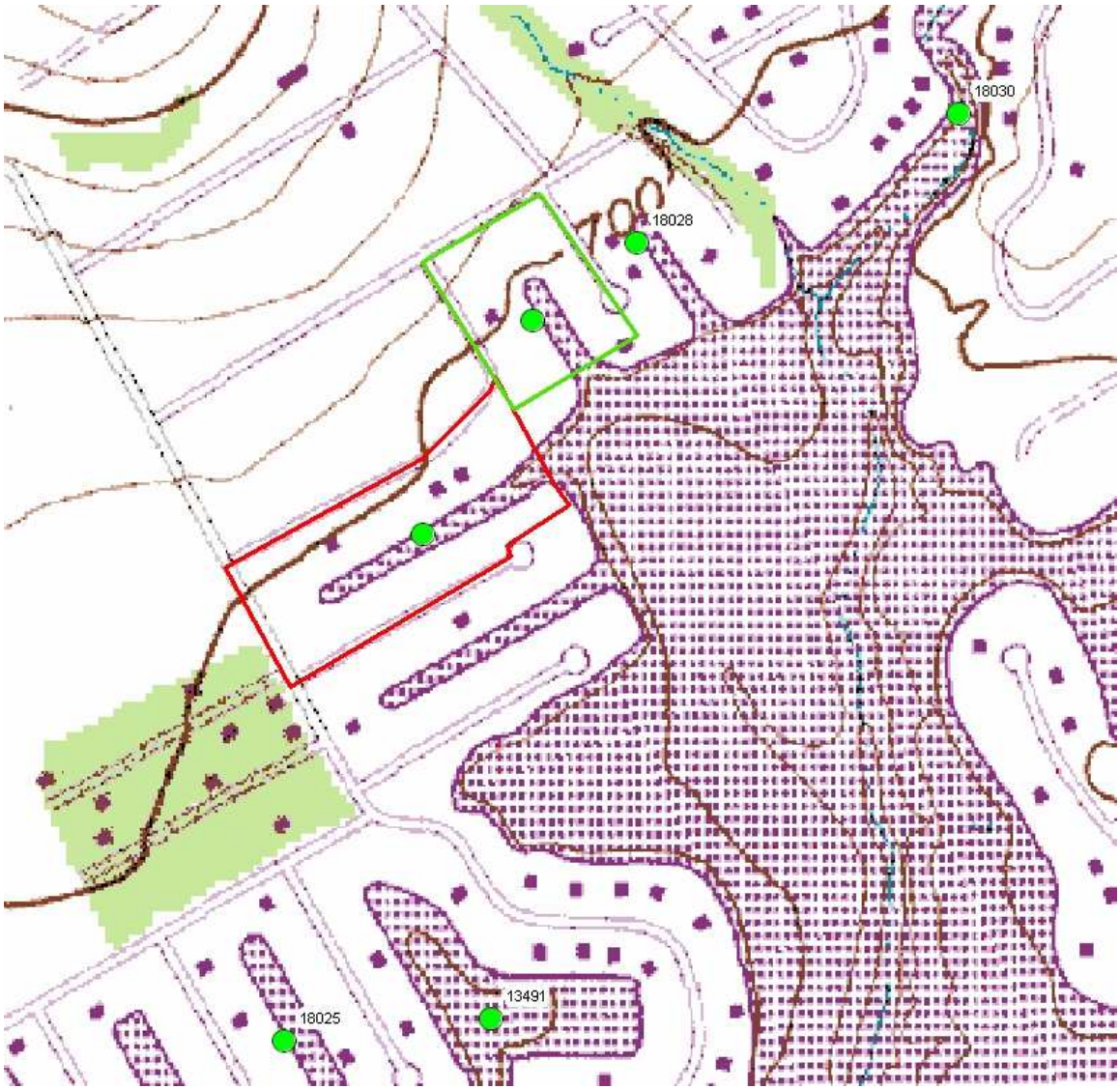
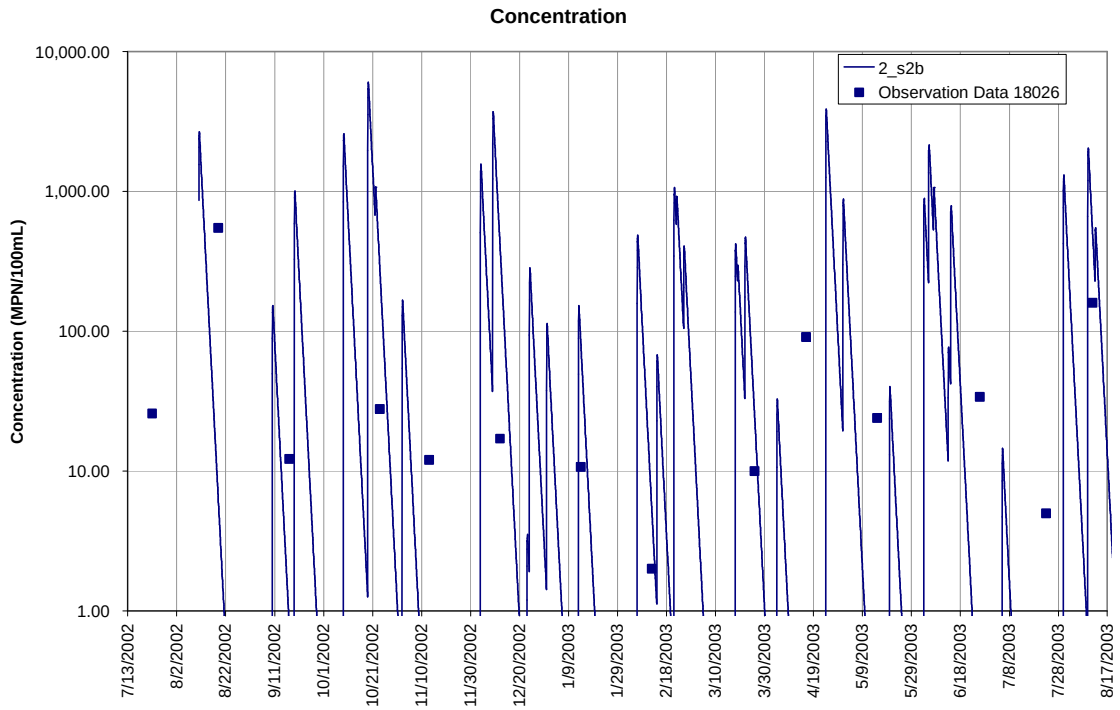


Figure E.32 Microwatershed Delineation for Nassau Bay II



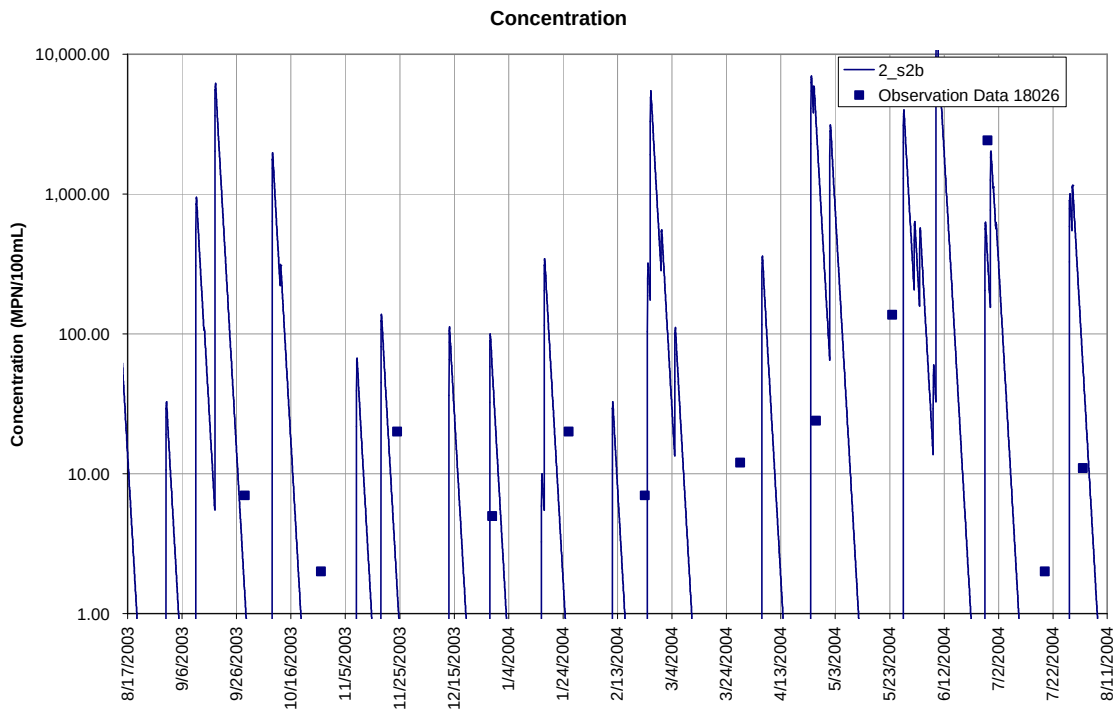


Figure E.33 Runoff models: Graphical Comparison of Observed vs. Modeled Bacteria Concentrations at Station 18026 located within the Nassau Bay II Canals

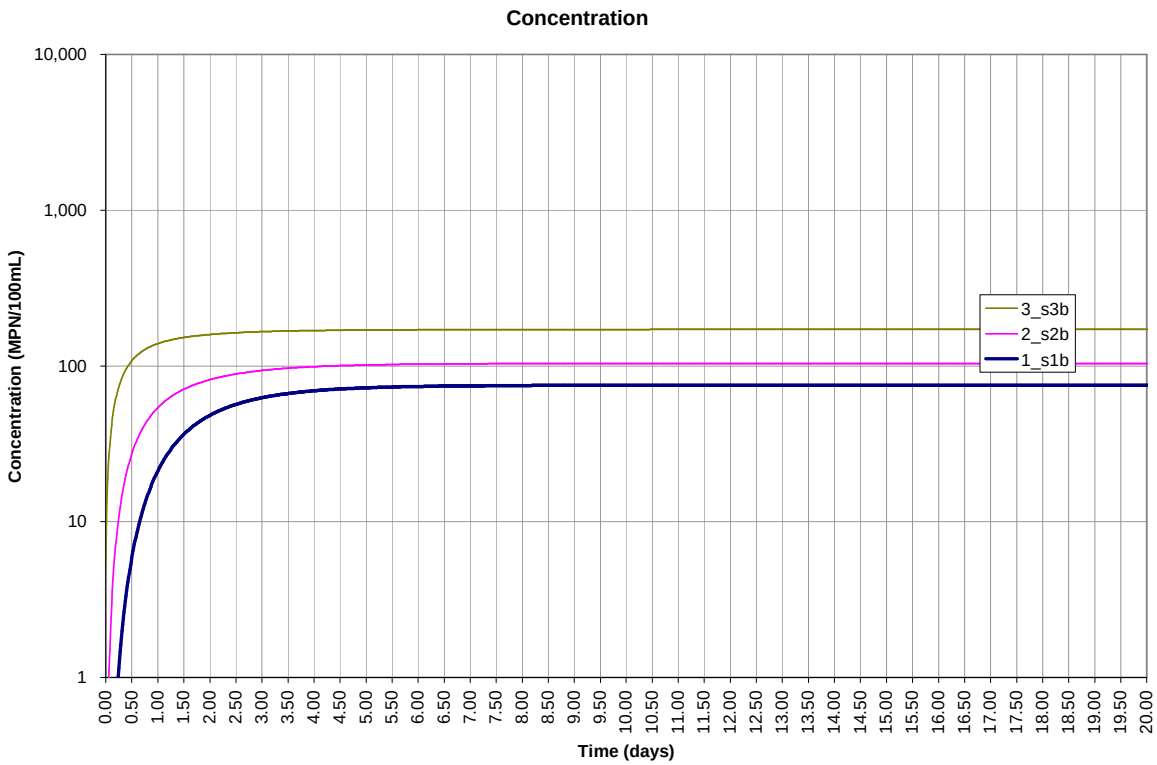


Figure E.34 Modeled Lake Boundary Condition for the Nassau Bay II Canals

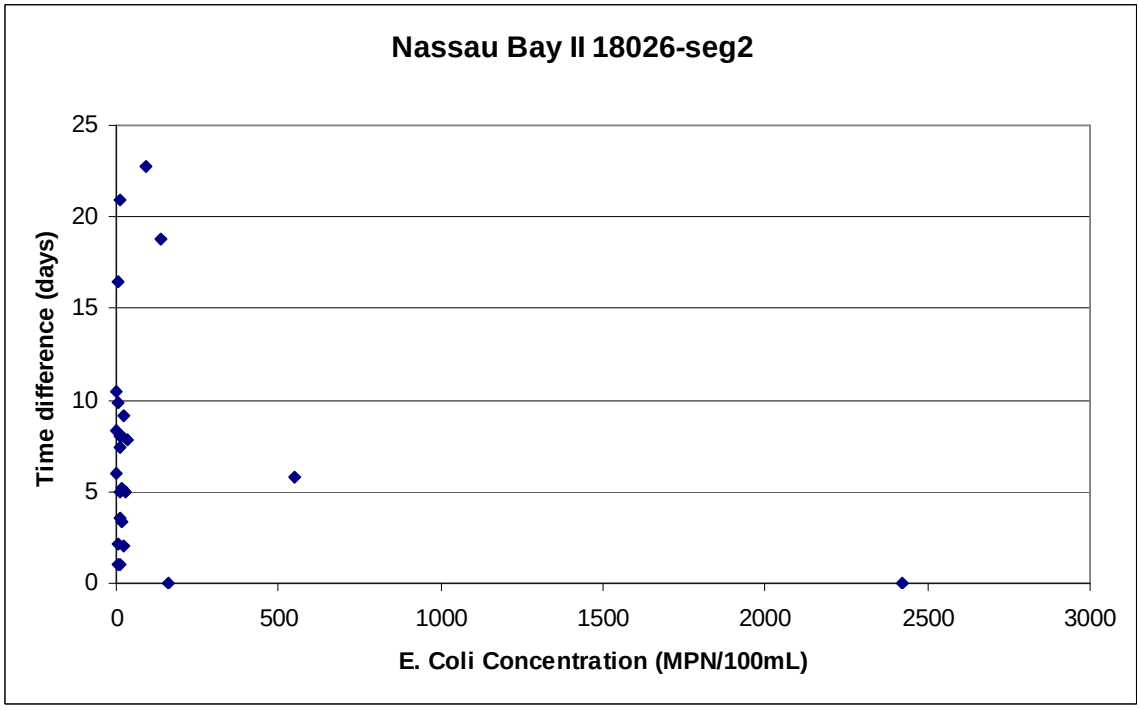


Figure E.35 Residual Plot for Station 18016 located within the Sky Harbor Canals

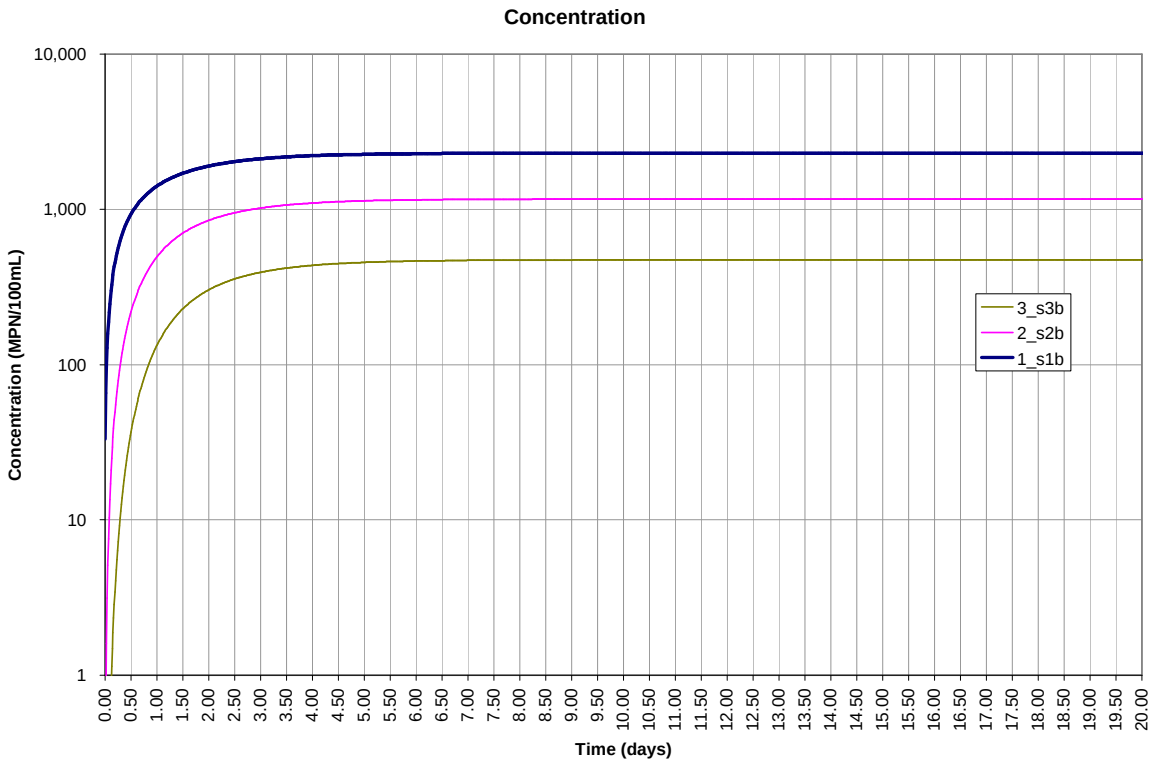


Figure E.36 Modeled Continuous Direct Discharge (septic) for Nassau Bay II canals

E.2.6 Waters Edge

The Water's Edge subdivision has two separate canal systems, Part I and Part II (Figure E.37). Part I was segmented into eight sections for the mass balance model. The direction of flow for Part I is from segment 1→2, 2→3, 3→4. 4→8, 6→7, 5→7, 7→8, 8→lake. Part II has two segments connected to the lake and the movement of water is from lake→segment 4→2, 2→3, 1→3, 3→lake.

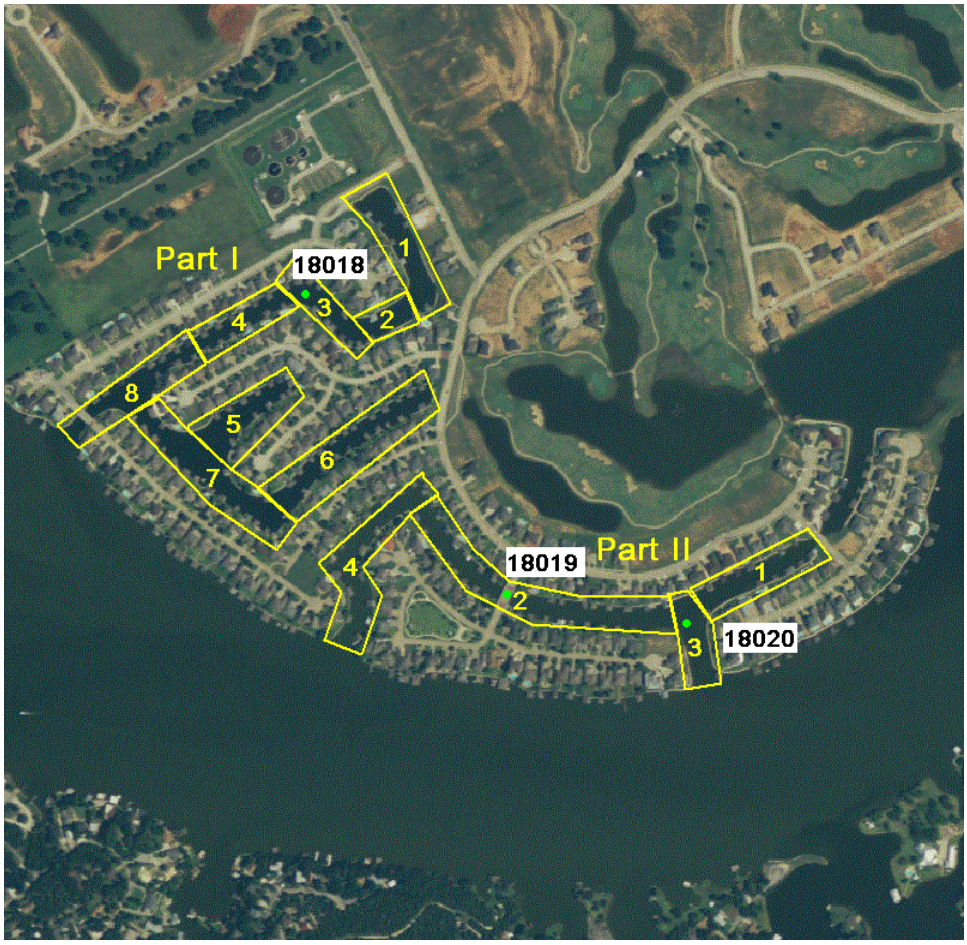


Figure E.37 Canal Segmentation for Modeling Water's Edge

The microwatersheds for Part II of Waters Edge is very isolated to the residential lots adjacent to the canals (Figure E.38).

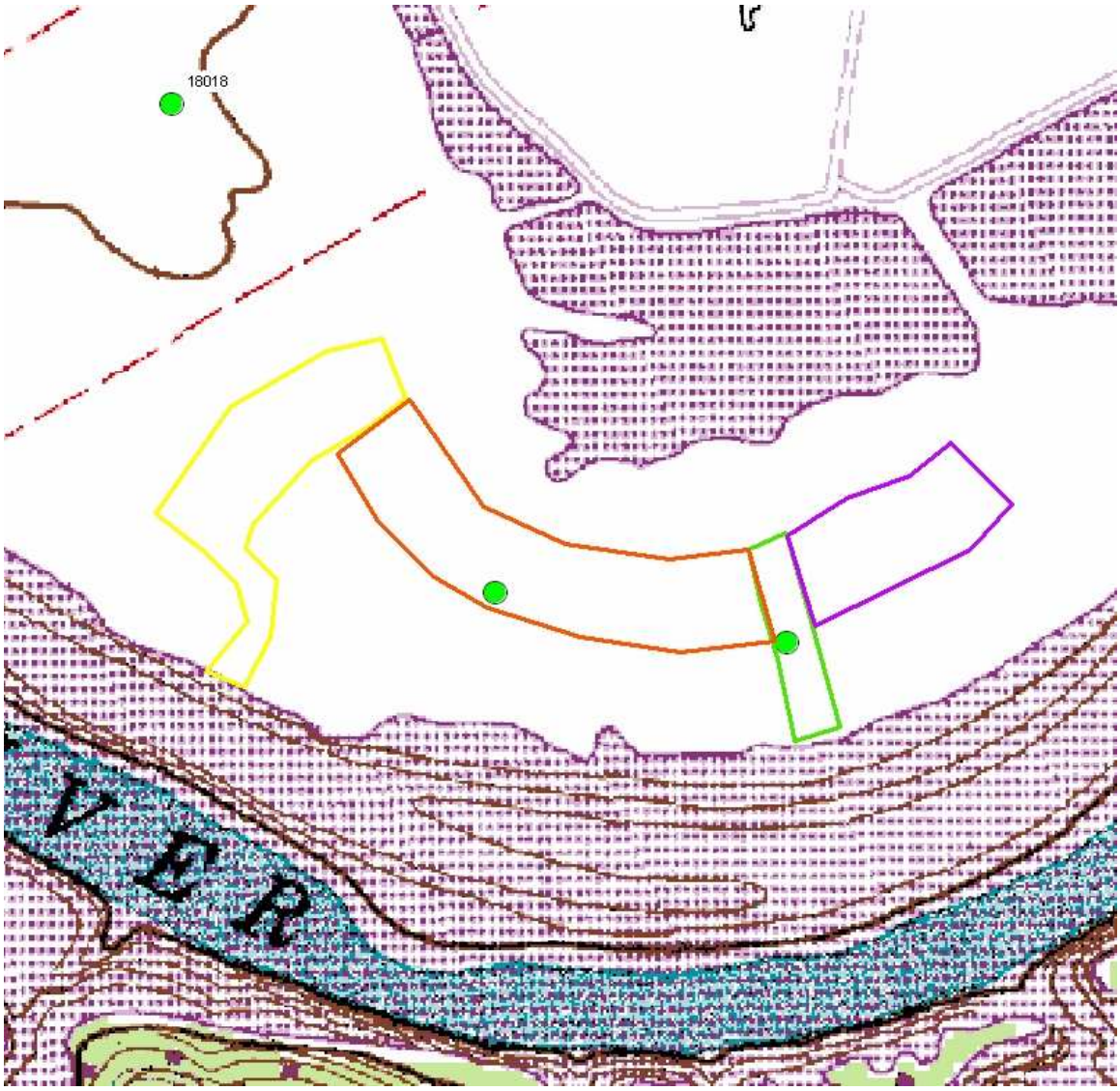


Figure E.38 Microwatershed Delineation for Waters Edge

The model predicted no significant concerns for water quality impairment due to bacteria from runoff sources. Further, the only potential source of bacteria would be a localized nonpoint source such as pets.

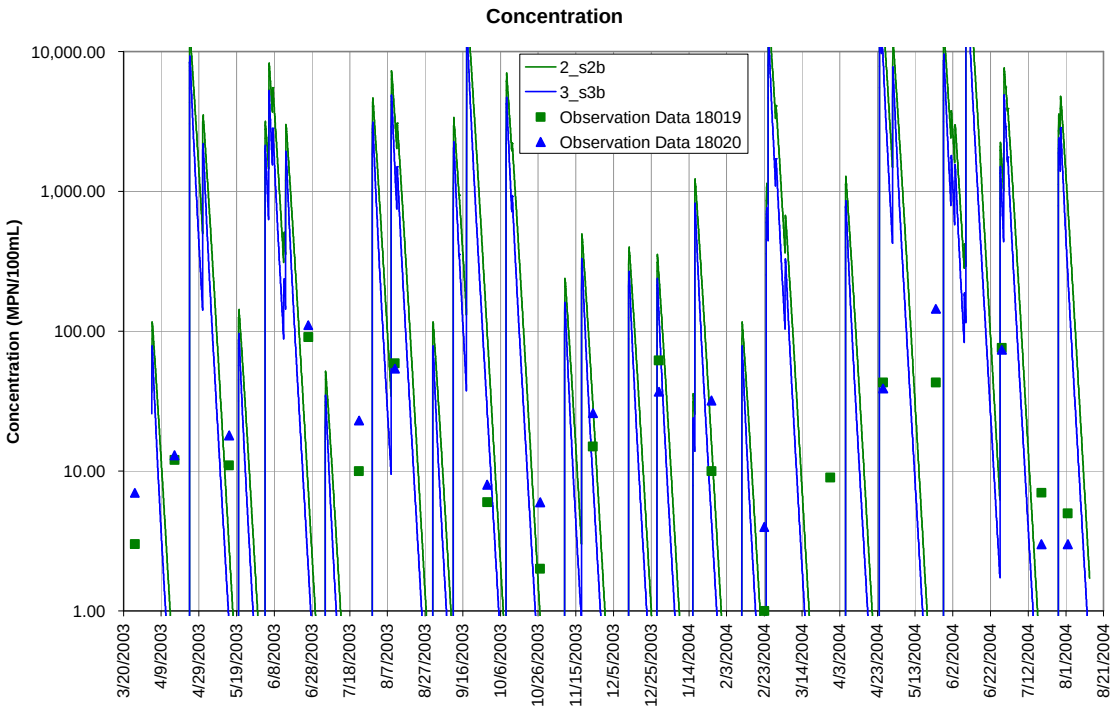


Figure E.39 Graphical Comparison of Observed vs. Modeled Bacteria Concentrations at Stations 18019 and 18020 located within the Water's Edge Canals

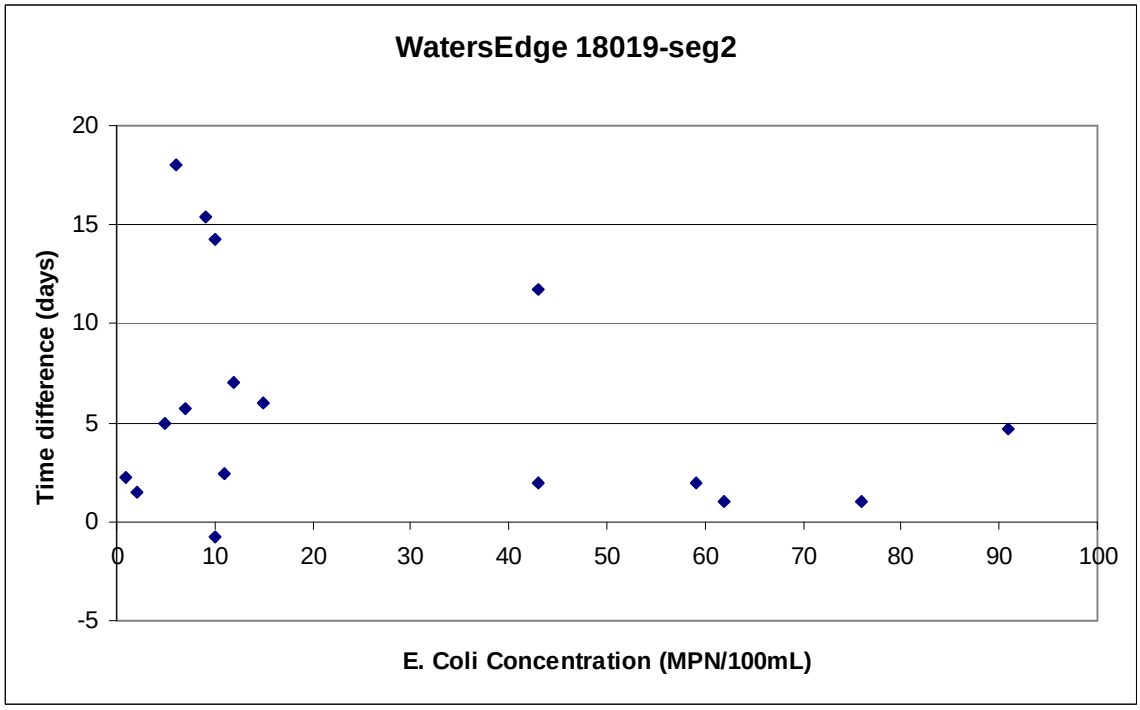


Figure E.40 Residual Plot for Station 18019 located within the Water's Edge Canals

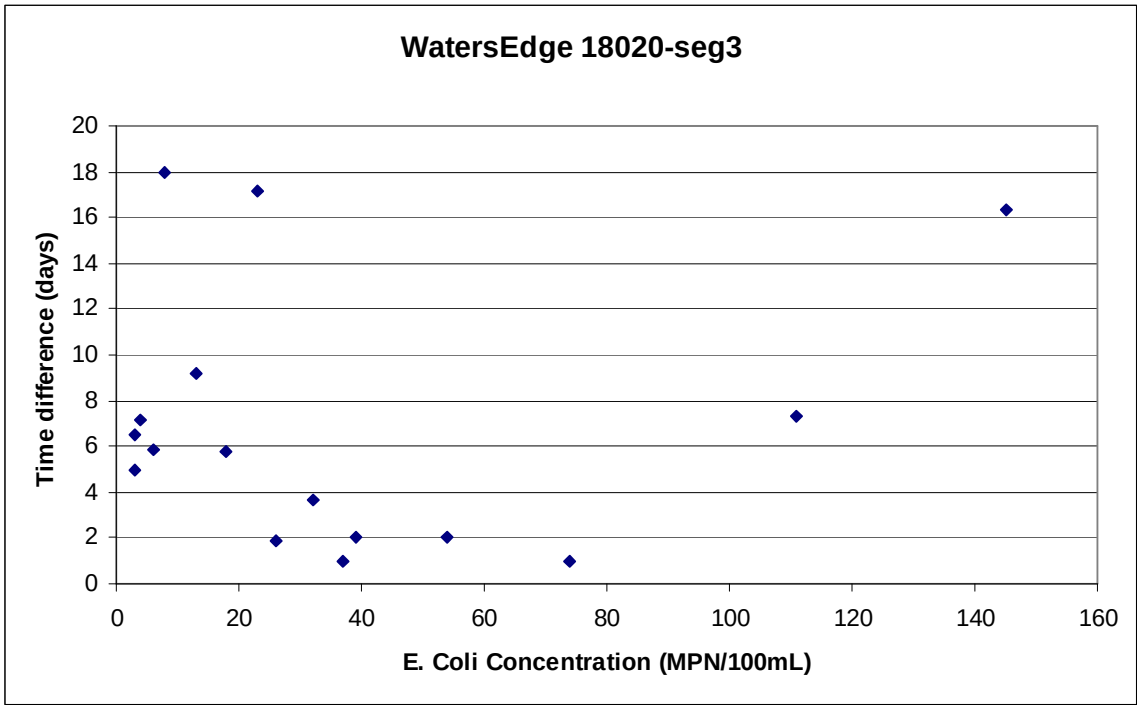


Figure E.41 Residual Plot for Station 18020 located within the Water's Edge Canals

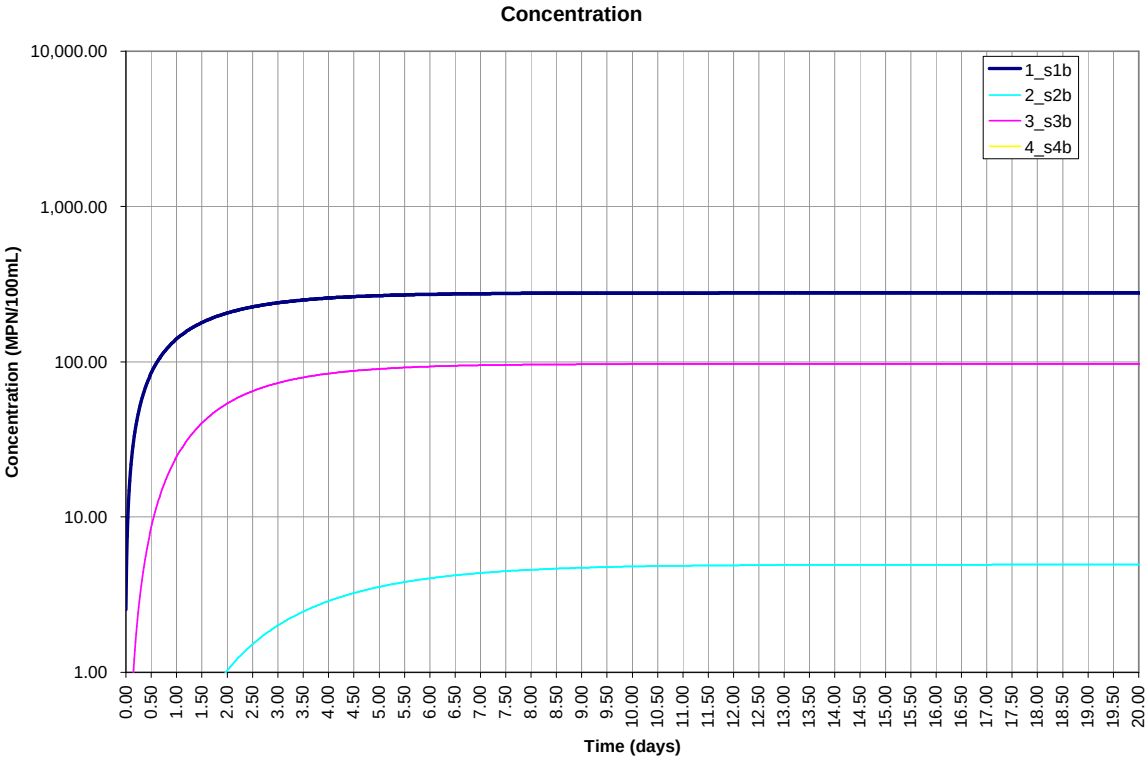


Figure E.42 Continuous Direct Discharge Water's Edge

E.2.7 Ports O' Call

The Ports O' Call subdivision has several canals. The canal monitored by station 18021 was divided into three segments for modeling the mass balance (Figure E.43). Again, this canal system has a very isolated microwatershed consisting of the residential lots immediately adjacent to the canal (Figure E.44).

Figure E.43 Canal Segmentation for Modeling Ports O' Call

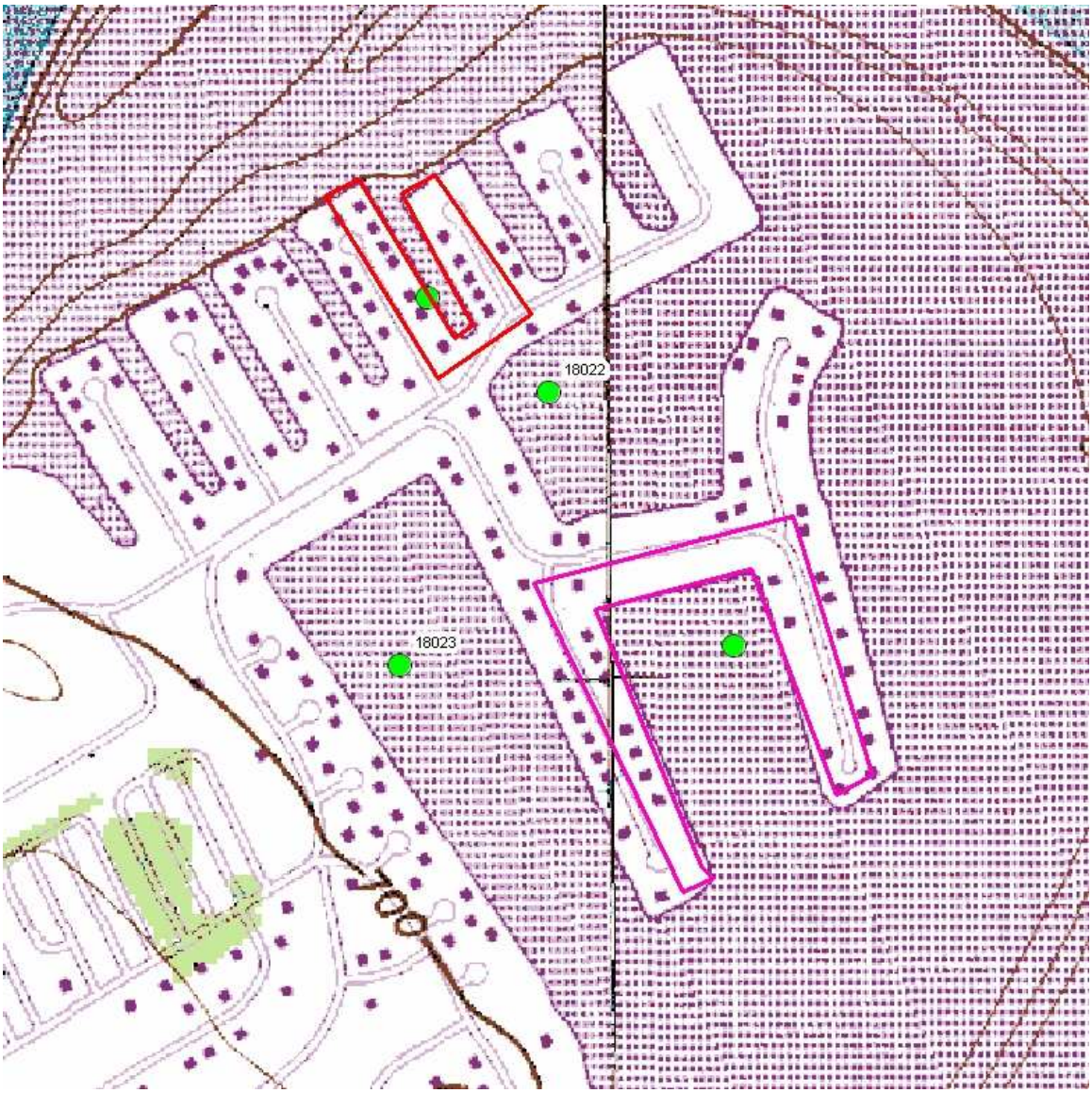
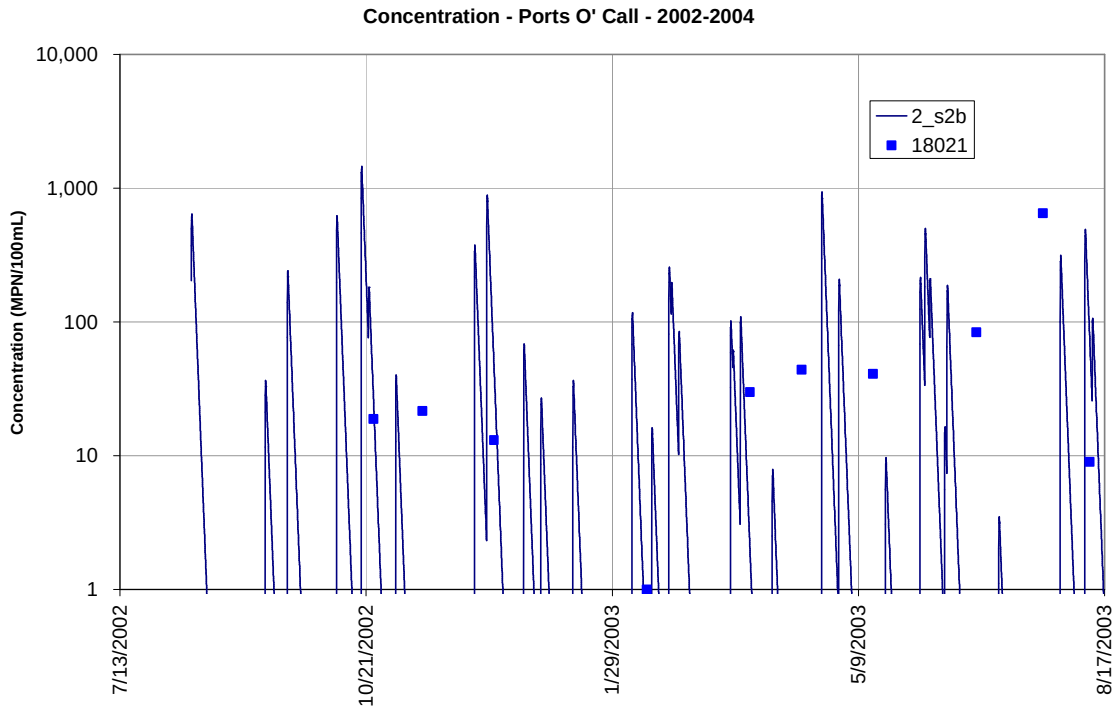


Figure E.44 Microwatershed Delineation for Ports O' Call and Indian Harbor



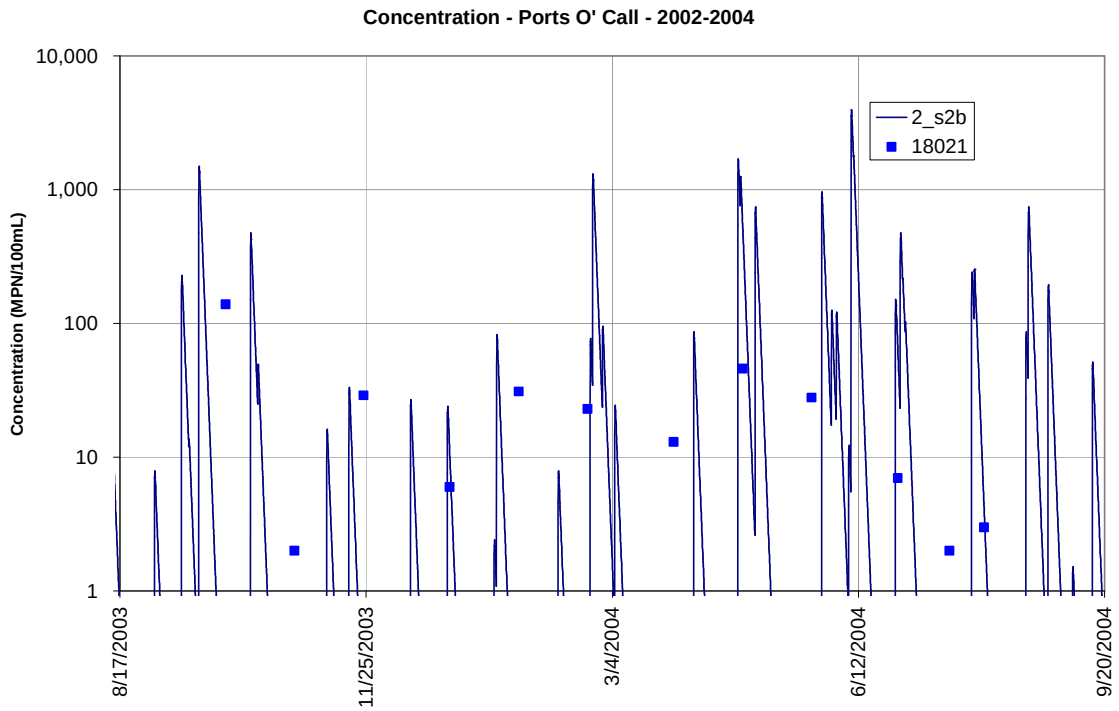


Figure E.45 Runoff model: Graphical Comparison of Observed vs. Modeled Bacteria Concentrations at Station 18021 located within the Ports O' Call Canal

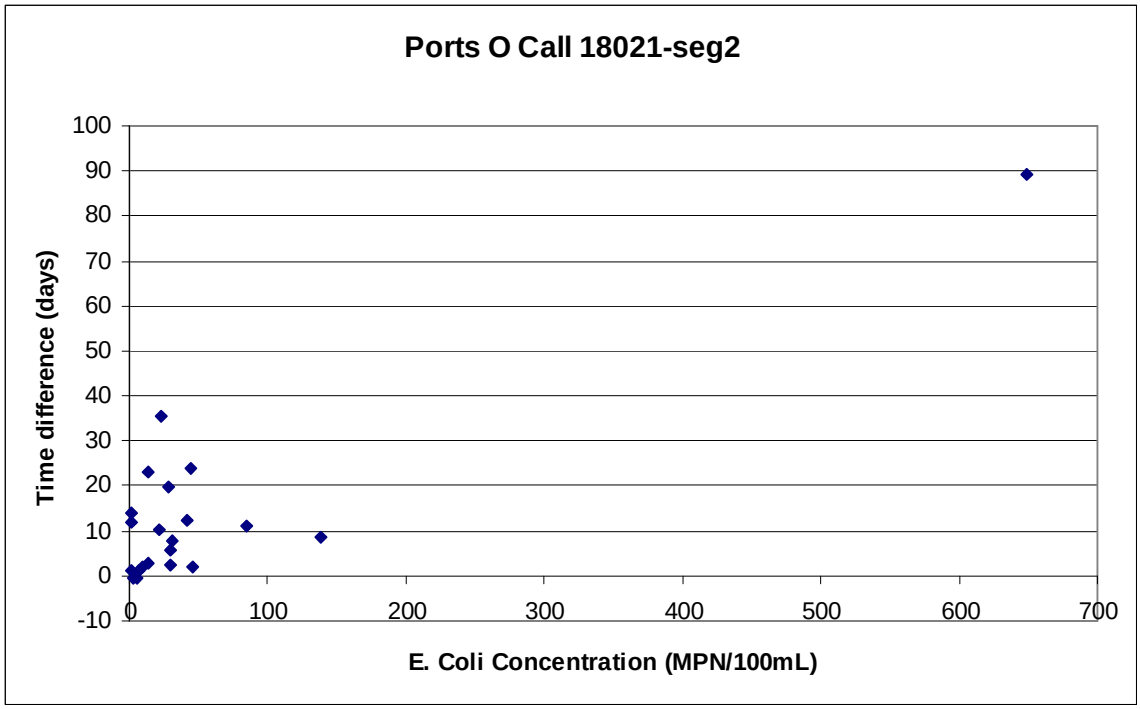


Figure E.46 Residual Plot for Station 18021 located within the modeled Ports O' Call canal

E.2.8 Indian Harbor

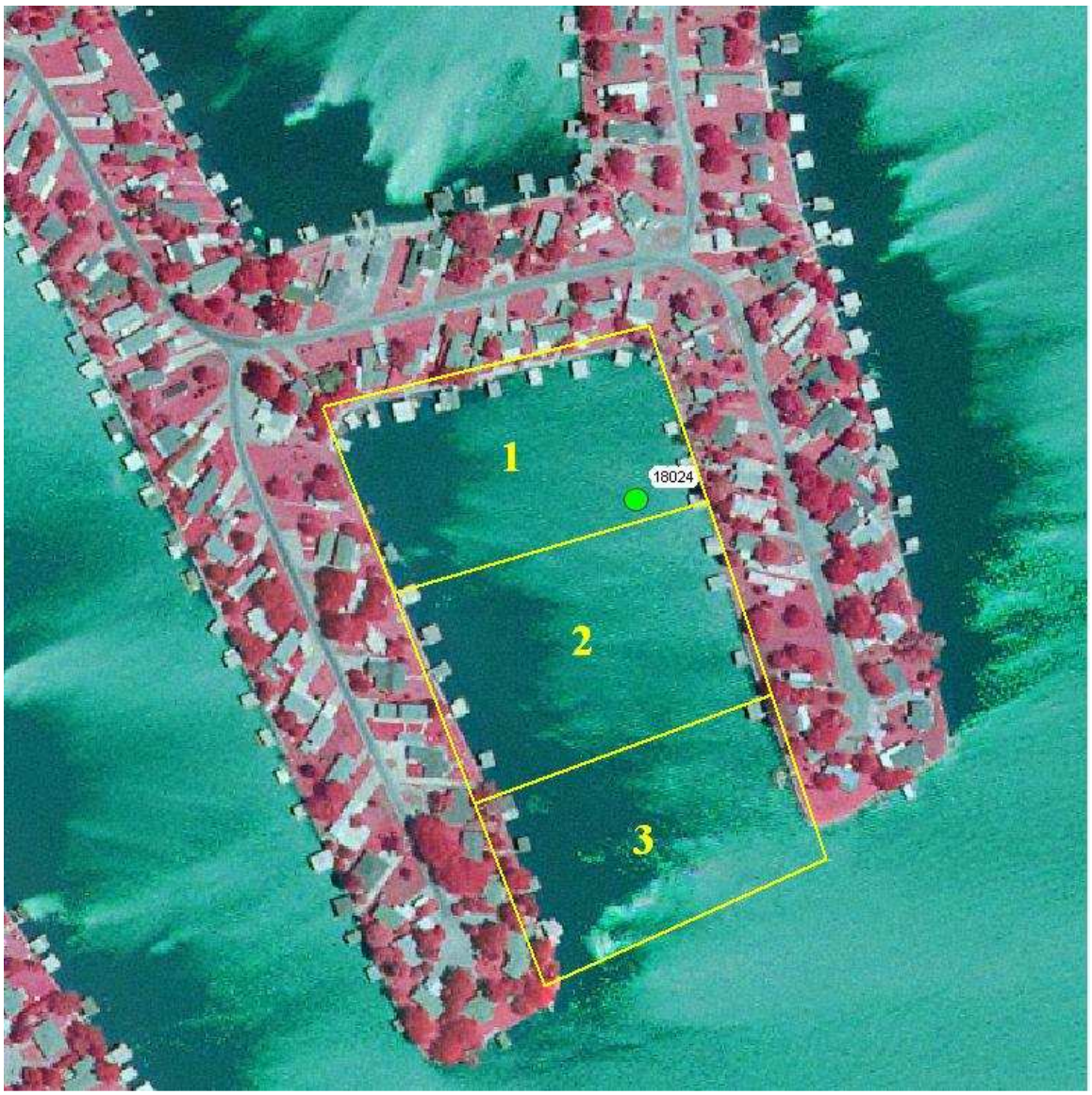


Figure E.47 Cove Segmentation for Modeling Indian Harbor

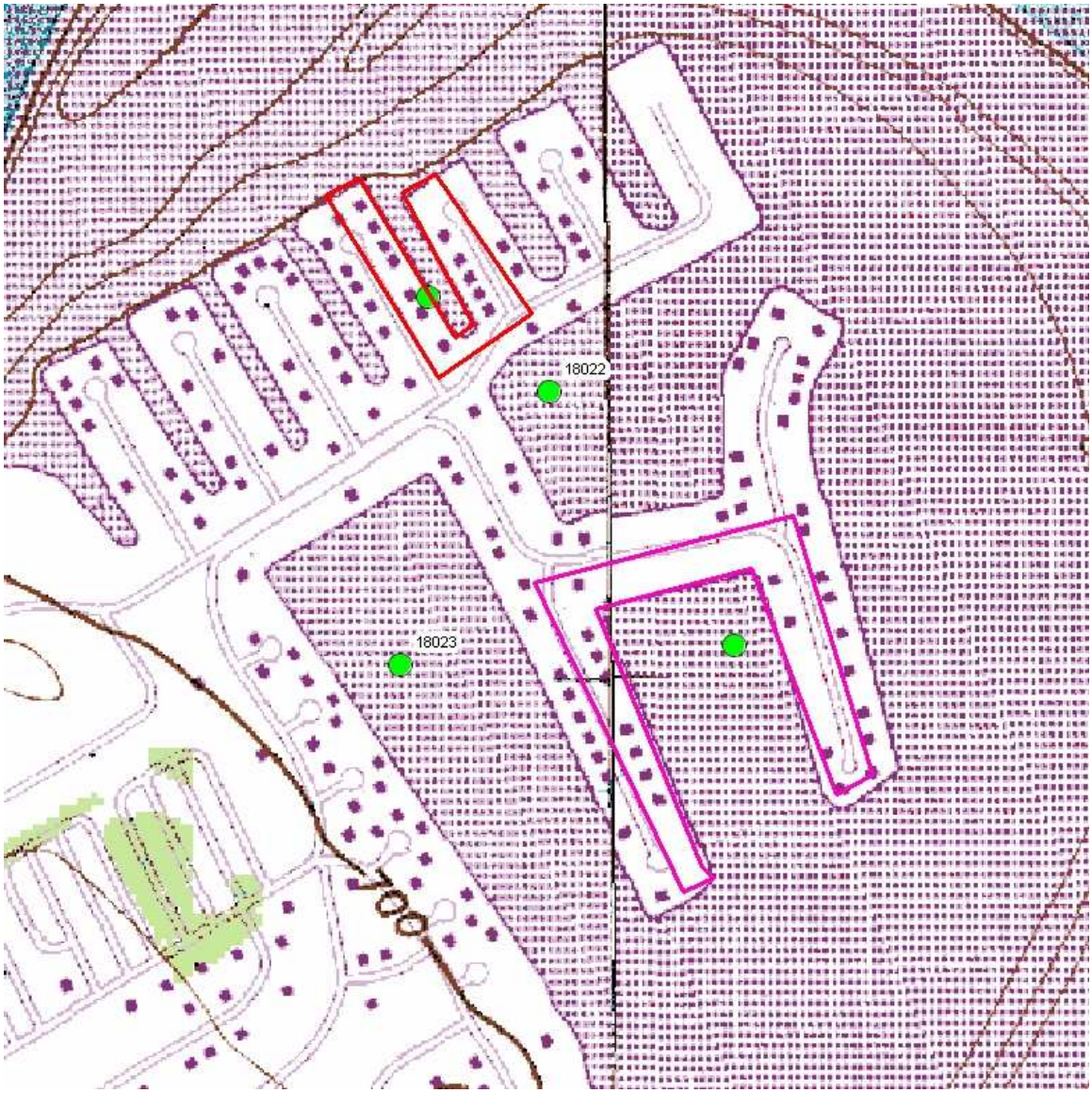
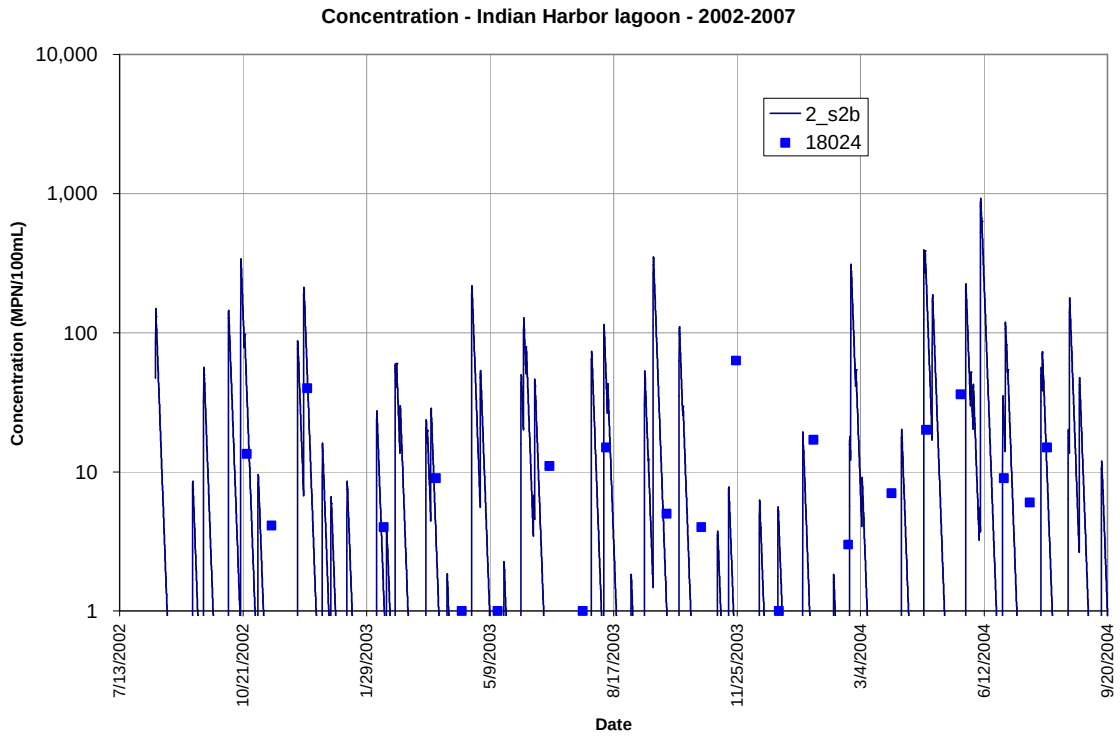


Figure E.48 Microwatershed Delineation for Ports O'Call and Indian Harbor



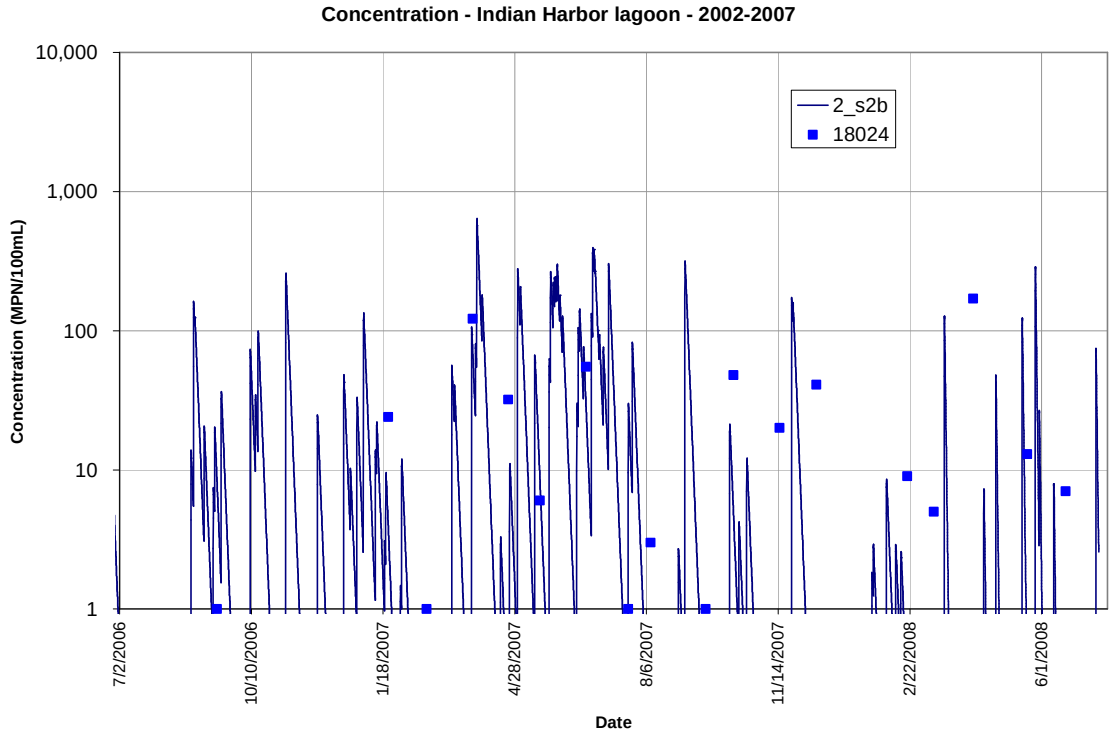


Figure E.49 Runoff model: Graphical Comparison of Observed vs. Modeled Bacteria Concentrations at Station 18024 located within the Indian Harbor Cove area

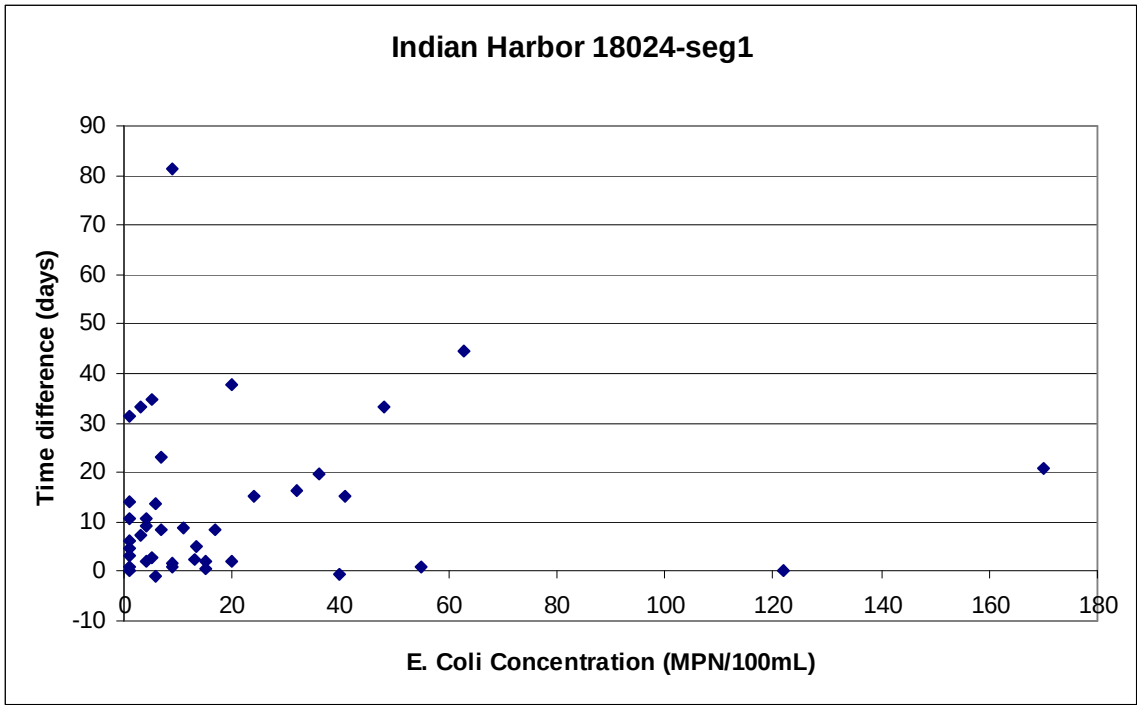


Figure E.50 Residual Plot for Station 18024 located within the Indian Harbor Cove area

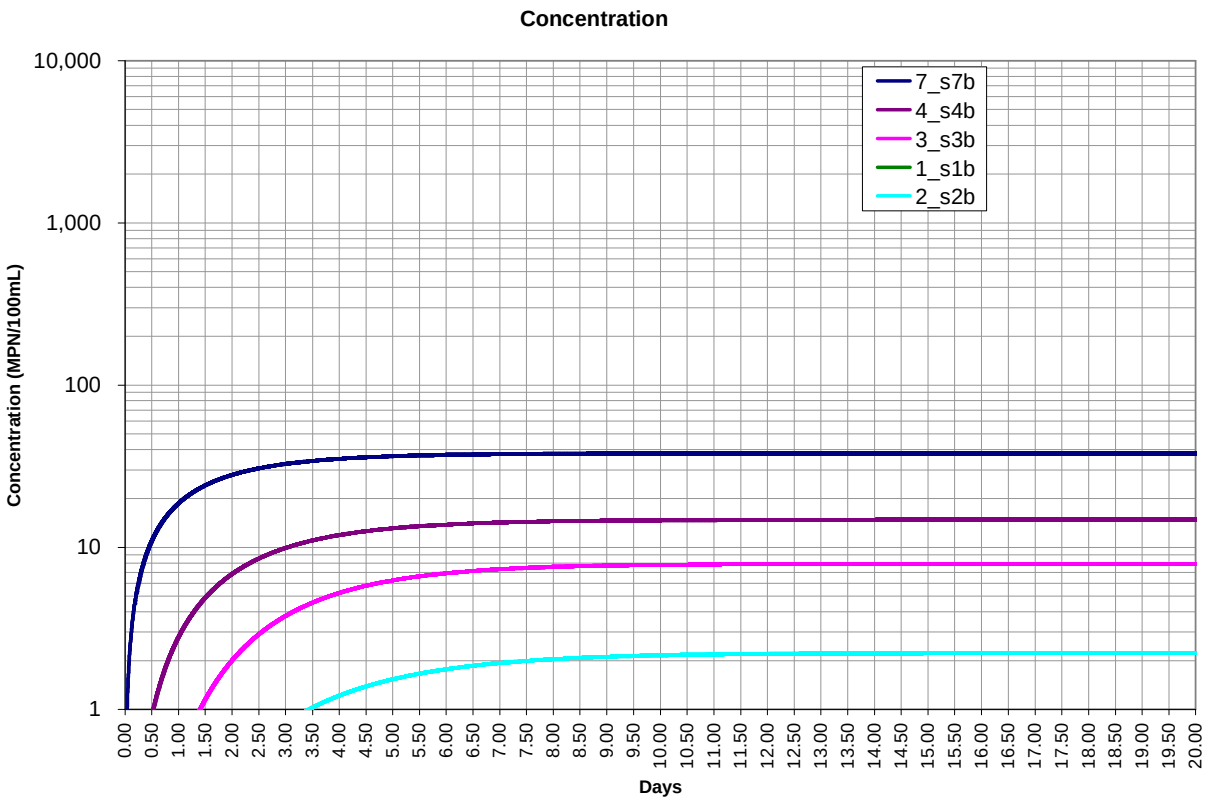


Figure E.51 Lake as source Boundary Condition for the Indian Harbor Cove area

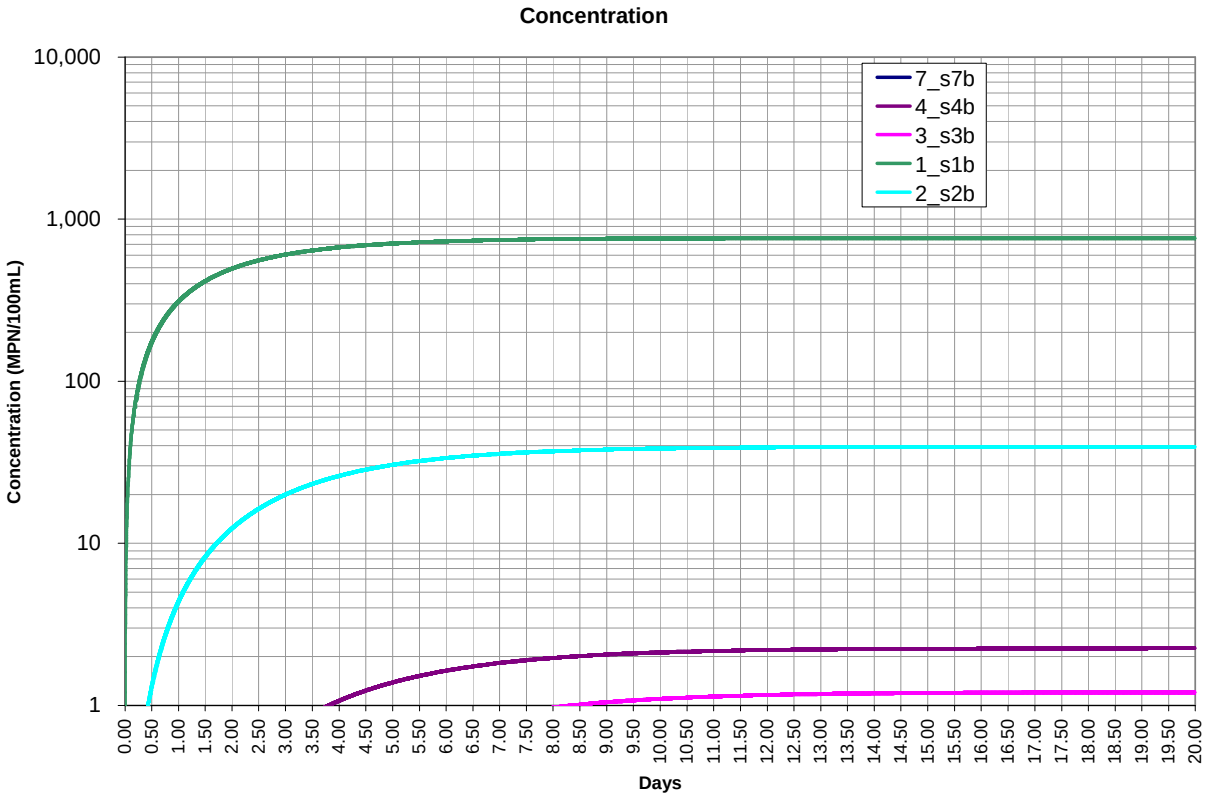


Figure E.52 Modeled Continuous Direct Discharge (septic) in the Indian Harbor Cove area

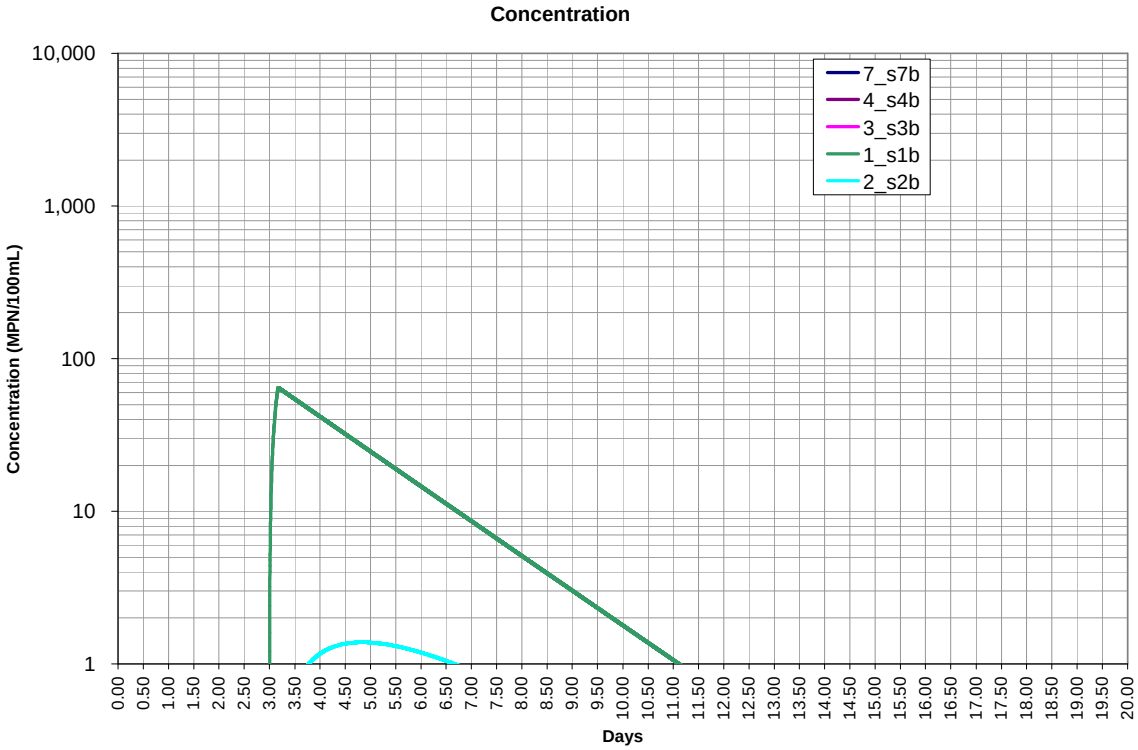


Figure E.53 Intermittent Direct Discharge (septic overload) in the Indian Harbor cove area

E.2.9 Port Ridglea

Figure E.54 Canal Segmentation for Modeling Port Ridgelea

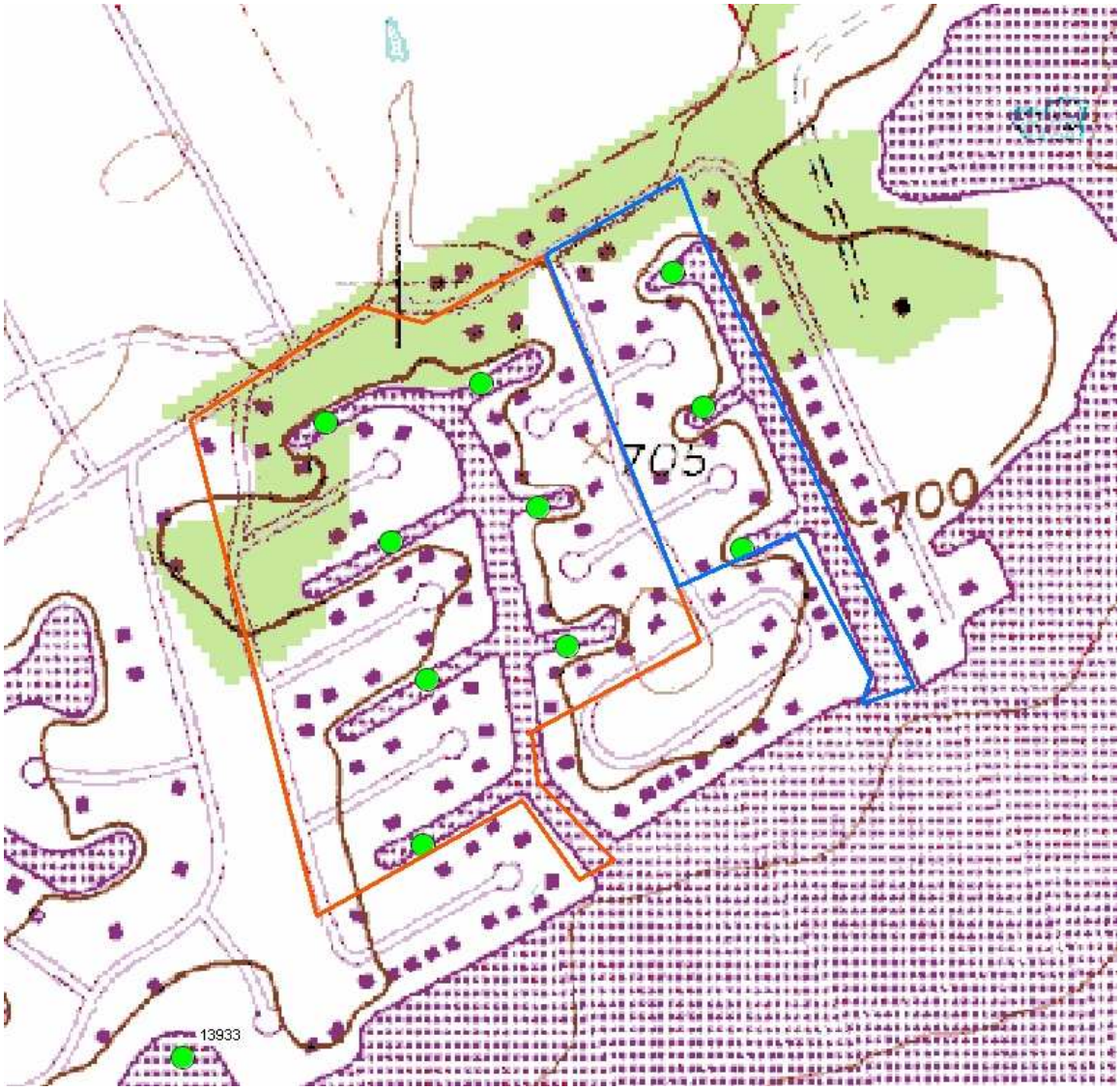
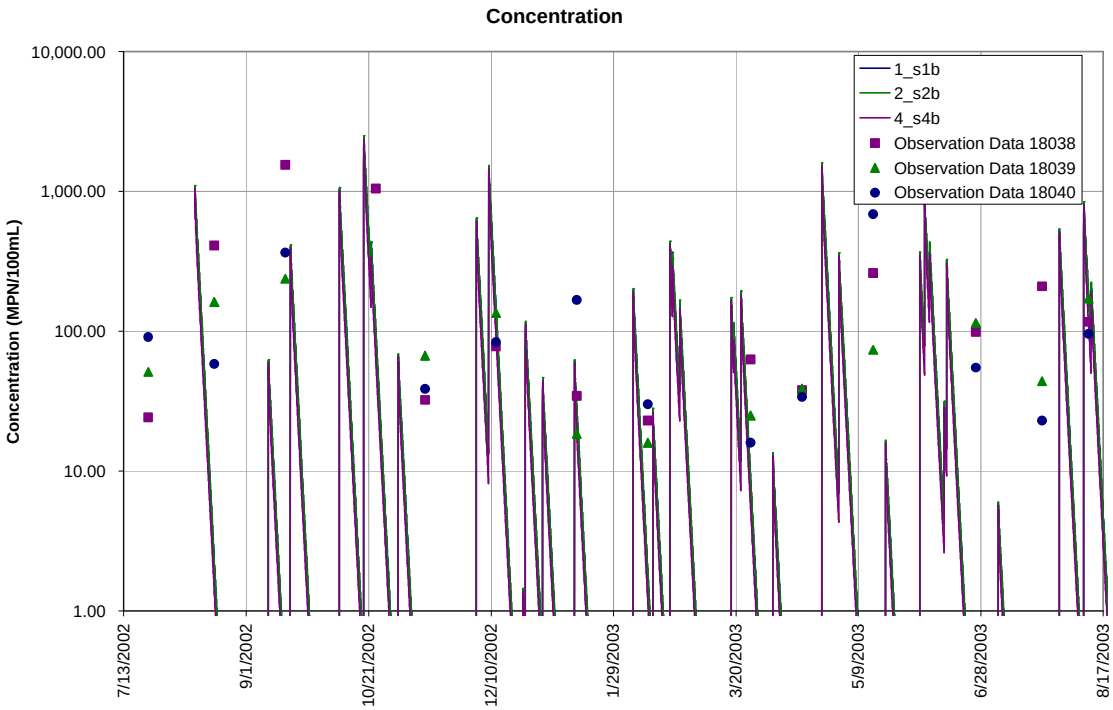


Figure E.55 Microwatershed Delineation for Port Ridglea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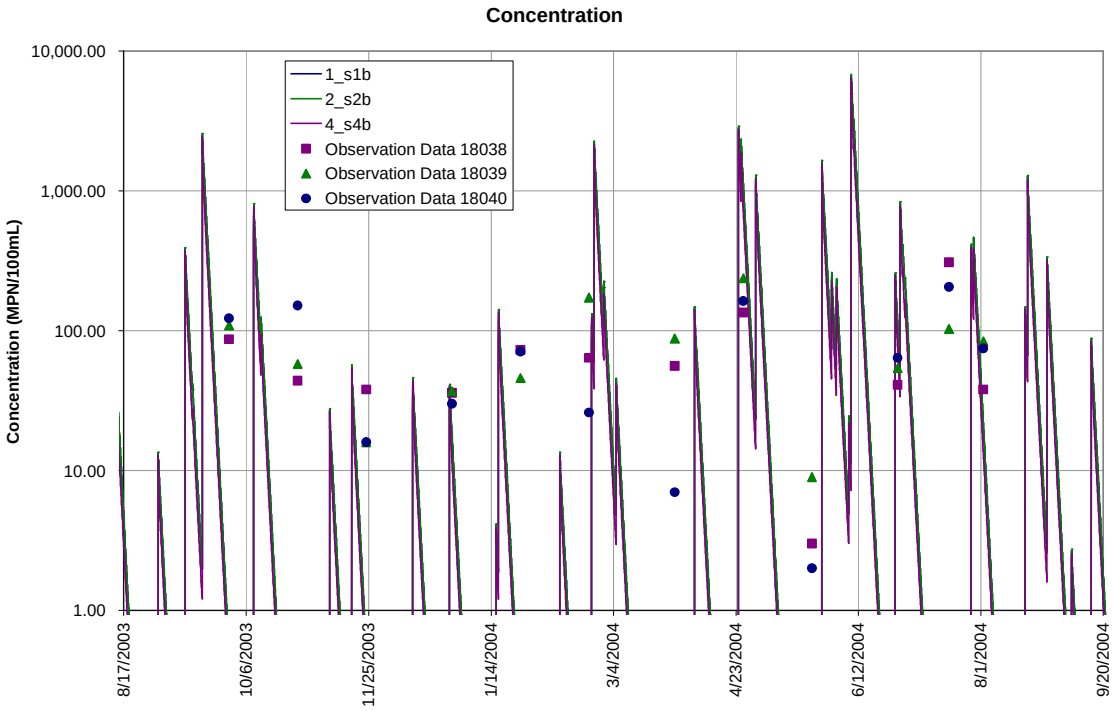
Observation Data 18040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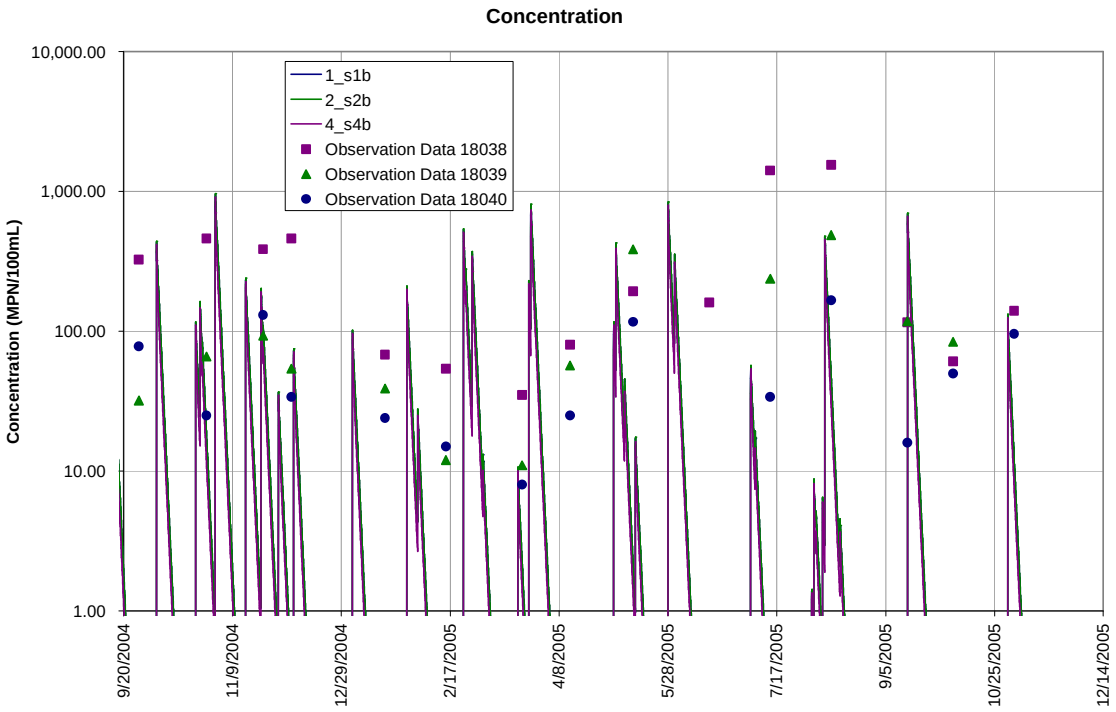
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Concentration (MPN/100mL)
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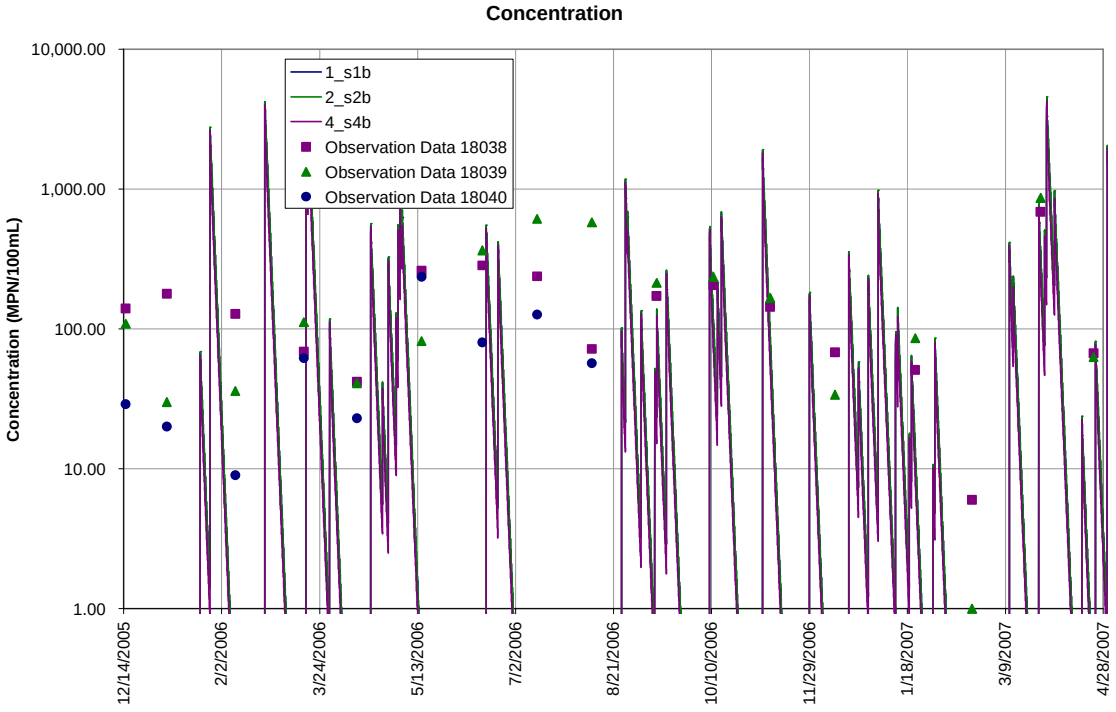
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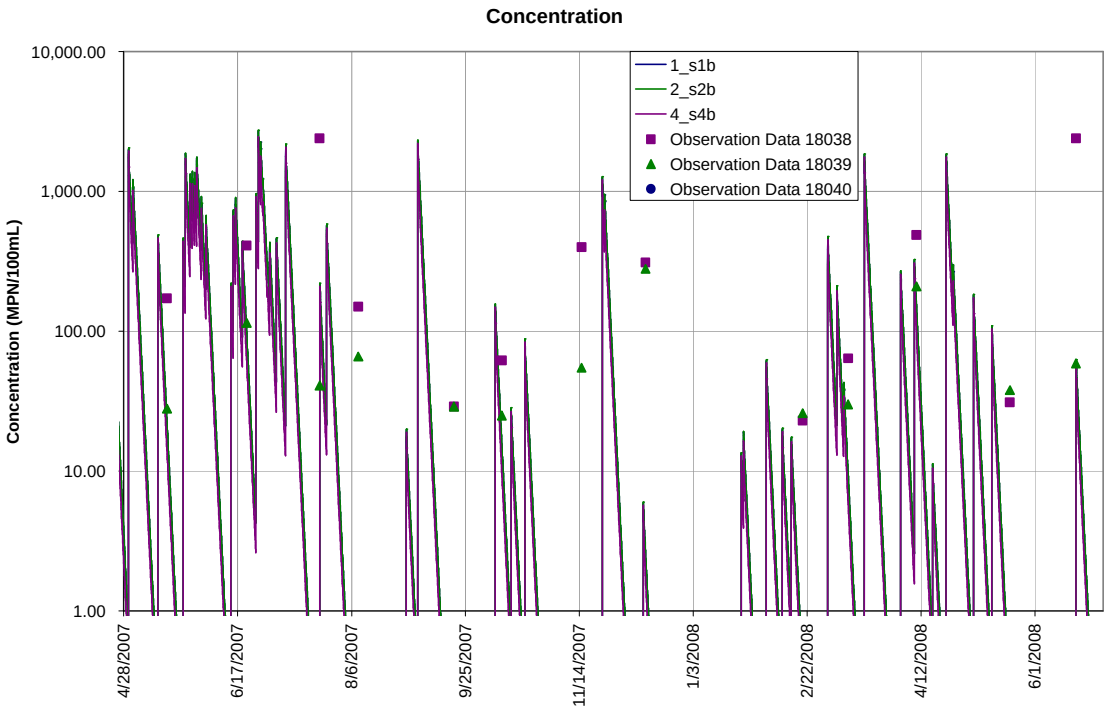


Figure E.56 Runoff model: Graphical Comparison of Observed vs. Modeled Bacteria Concentrations at Stations 18036, 18039, and 18040 located within the Port Ridglea Canals

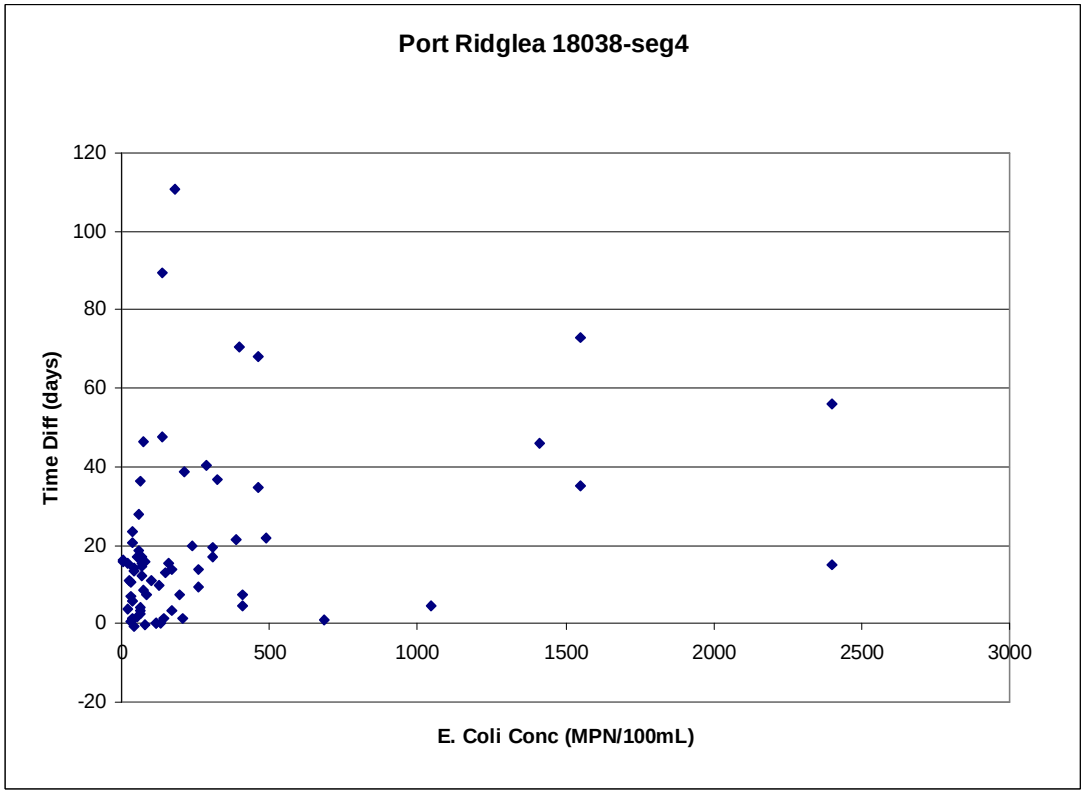


Figure E.57 Residual Plot for Station 18038 located within the Port Ridglea Canals

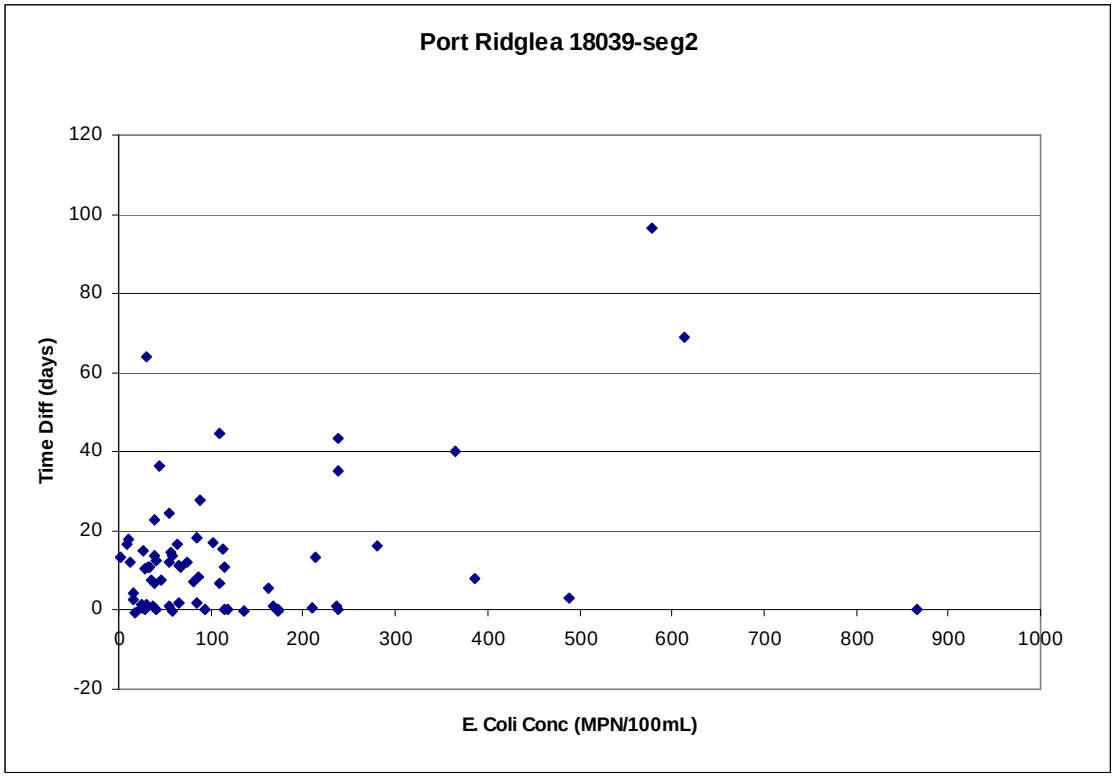


Figure E.58 Residual Plot for Station 18039 located within the Port Ridglea Canals

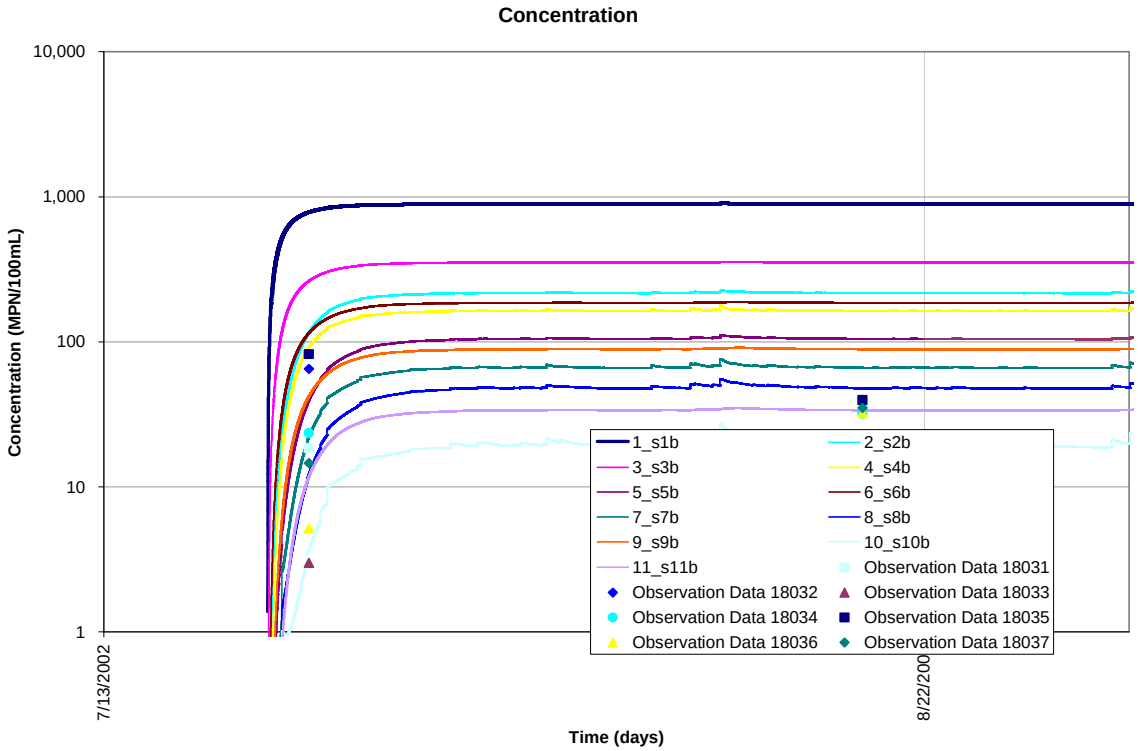


Figure E.59 Modeled Continuous Direct Discharge (septic) in Port Ridglea Canals

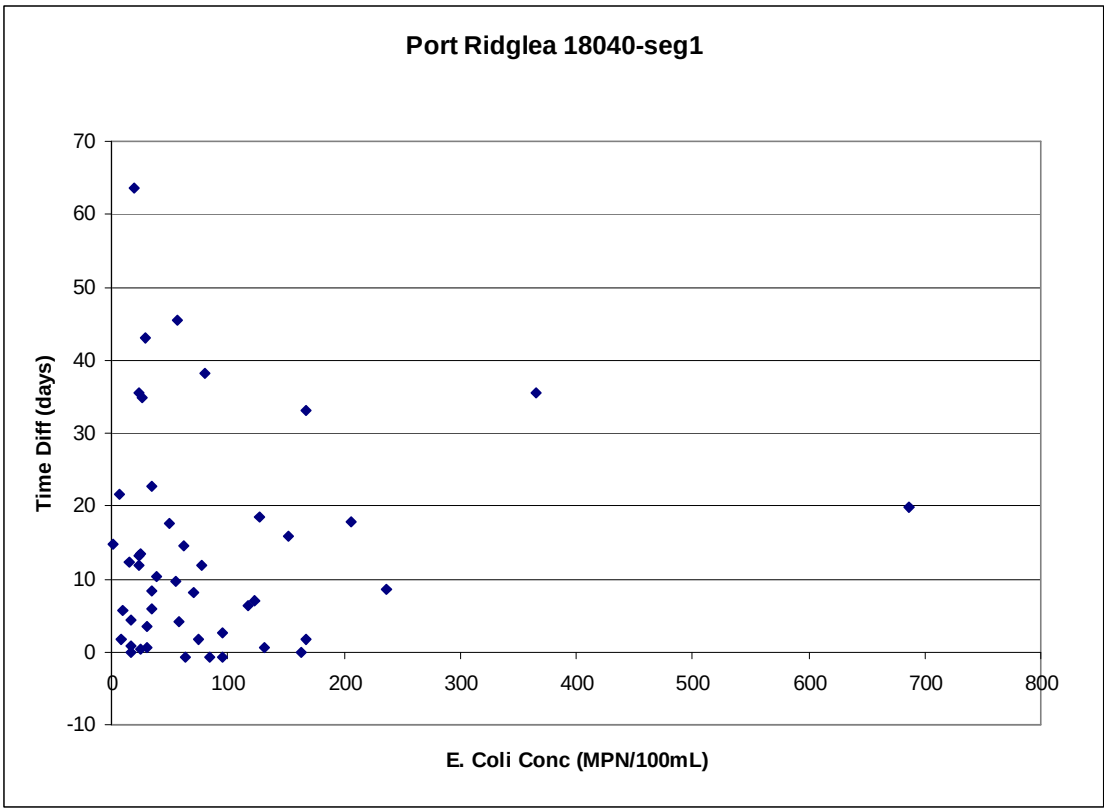


Figure E.60 Residual Plot for Station 18040 located within the Port Ridglea Canals

E.2.10 Blue Water Shores

Figure E.61 Canal Segmentation for Modeling Blue Water Shores

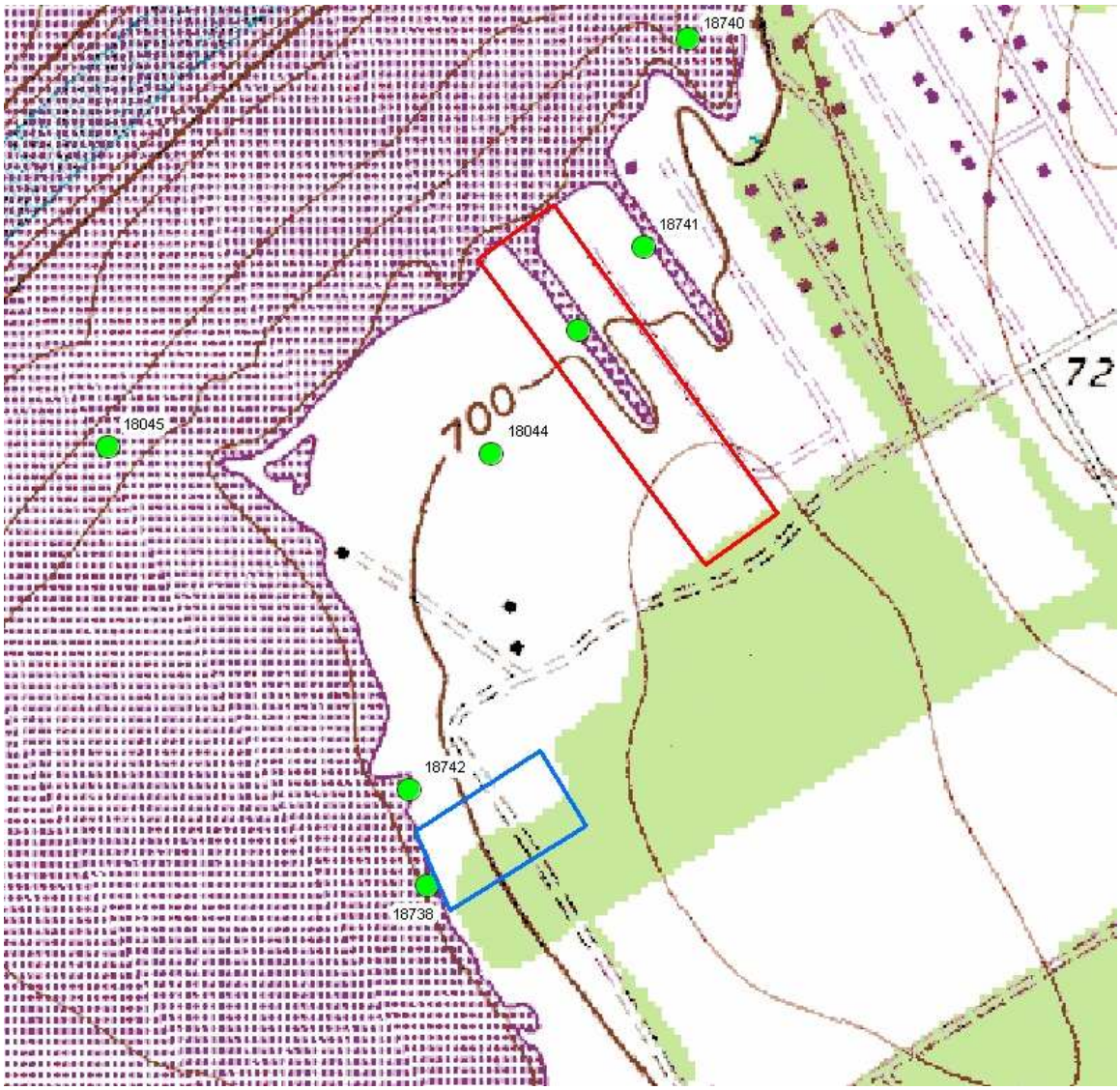
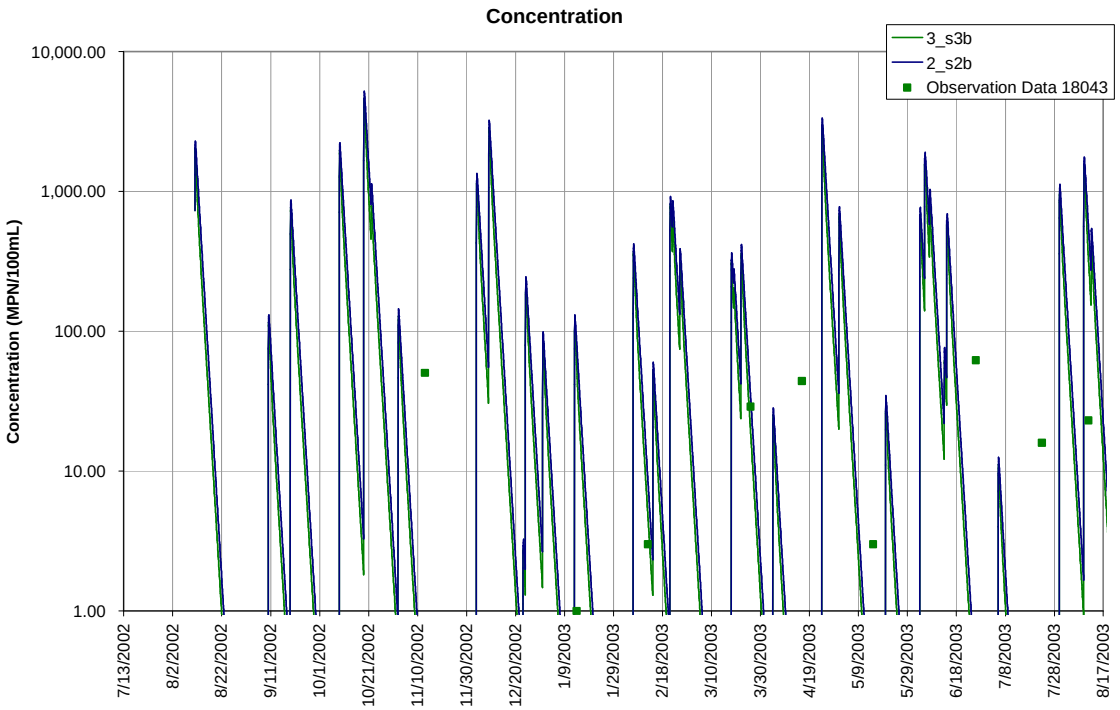
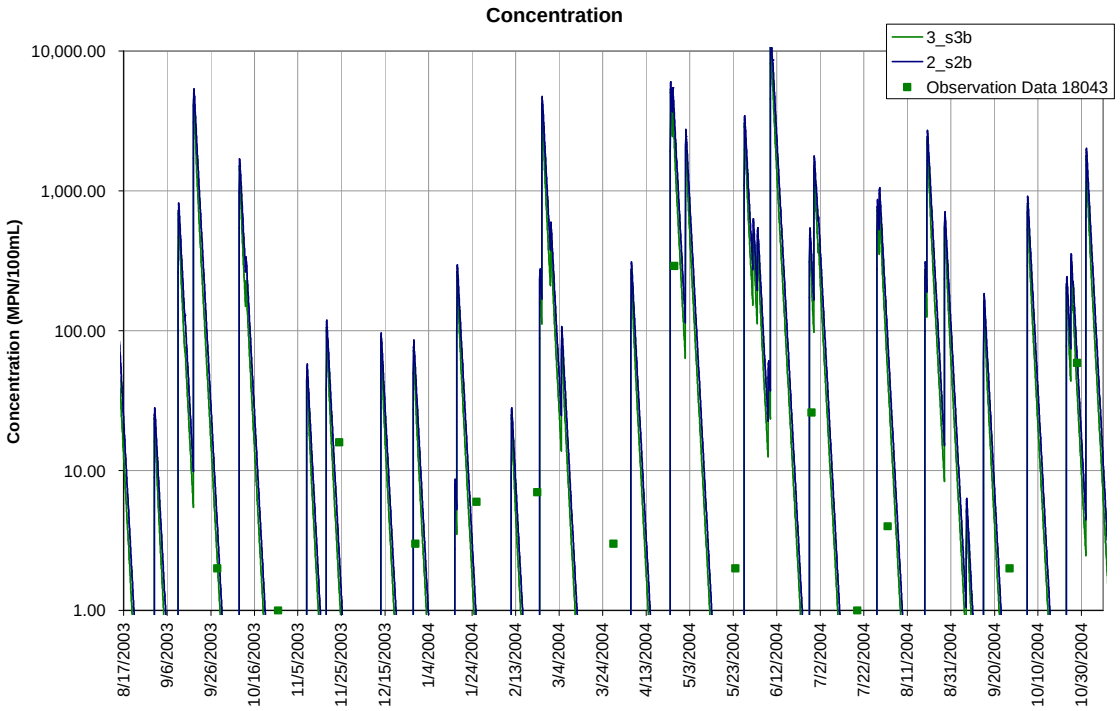


Figure E.62 Microwatershed Delineation for Blue Water Shores


Concentration
3_s3b
2_s2b
Observation Data 18043
Concentration (MPN/100mL)
10,000.00
1,000.00
100.00
10.00
1.00
7/13/2002
8/2/2002
8/22/2002
9/11/2002
10/1/2002
10/21/2002
11/10/2002
11/30/2002
12/20/2002
1/9/2003
1/29/2003
2/18/2003
3/10/2003
3/30/2003
4/19/2003
5/9/2003
5/29/2003
6/18/2003
7/8/2003
7/28/2003
8/17/2003


Concentration
3_s3b
2_s2b
Observation Data 18043
Concentration (MPN/100mL)
10,000.00
1,000.00
100.00
10.00
1.00
8/17/2003
9/6/2003
9/26/2003
10/16/2003
11/5/2003
11/25/2003
12/15/2003
1/4/2004
1/24/2004
2/13/2004
3/4/2004
3/24/2004
4/13/2004
5/3/2004
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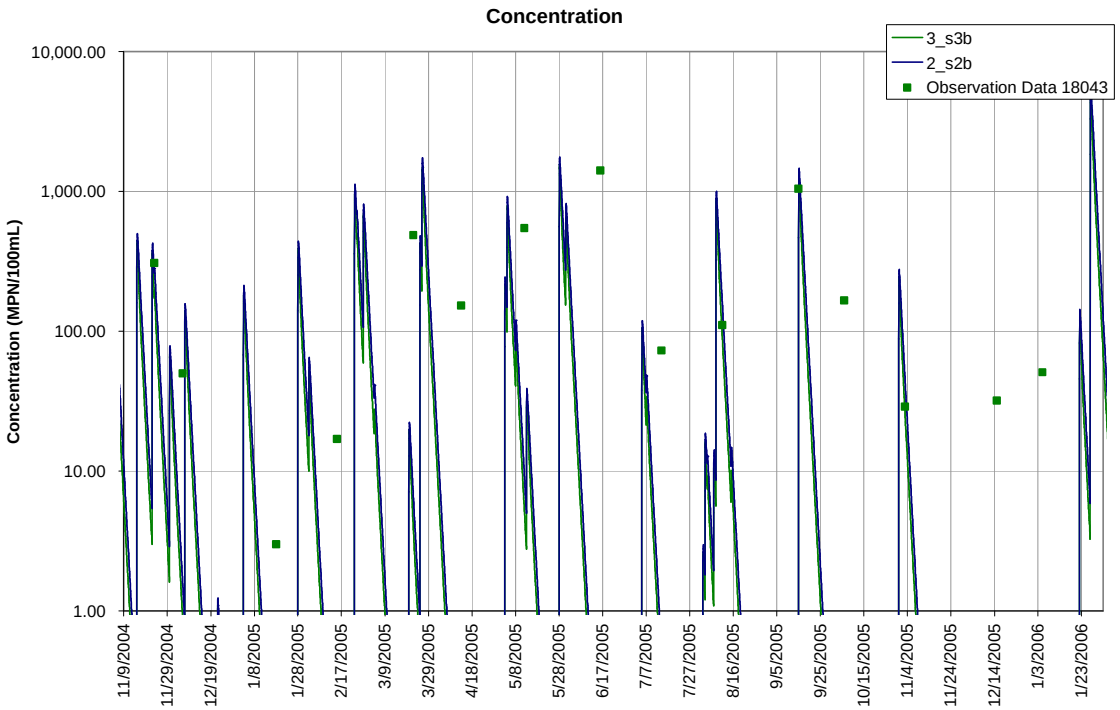
10/10/2004
10/30/2004



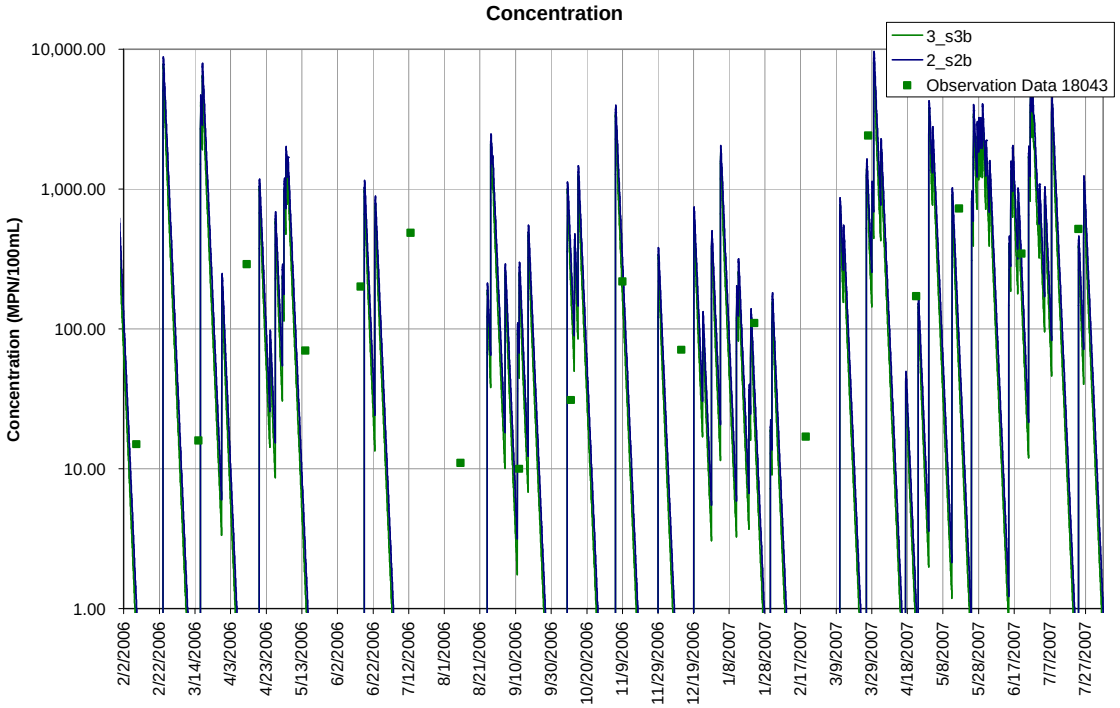


Figure E.63 Runof model: Graphical Comparison of Observed vs. Modeled Bacteria Concentrations at Station 18043 located within the Blue Water Shores Canal

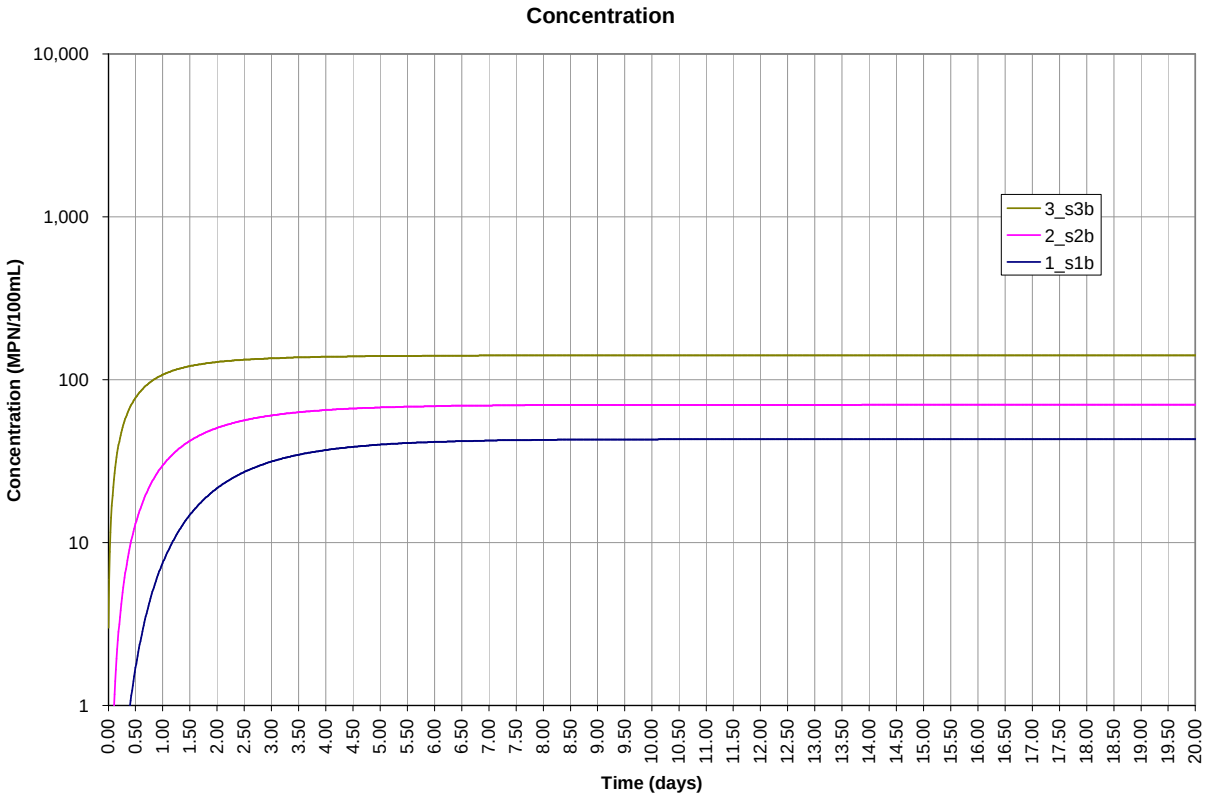


Figure E.64 Modeled Lake Boundary Condition for Blue Water Shores

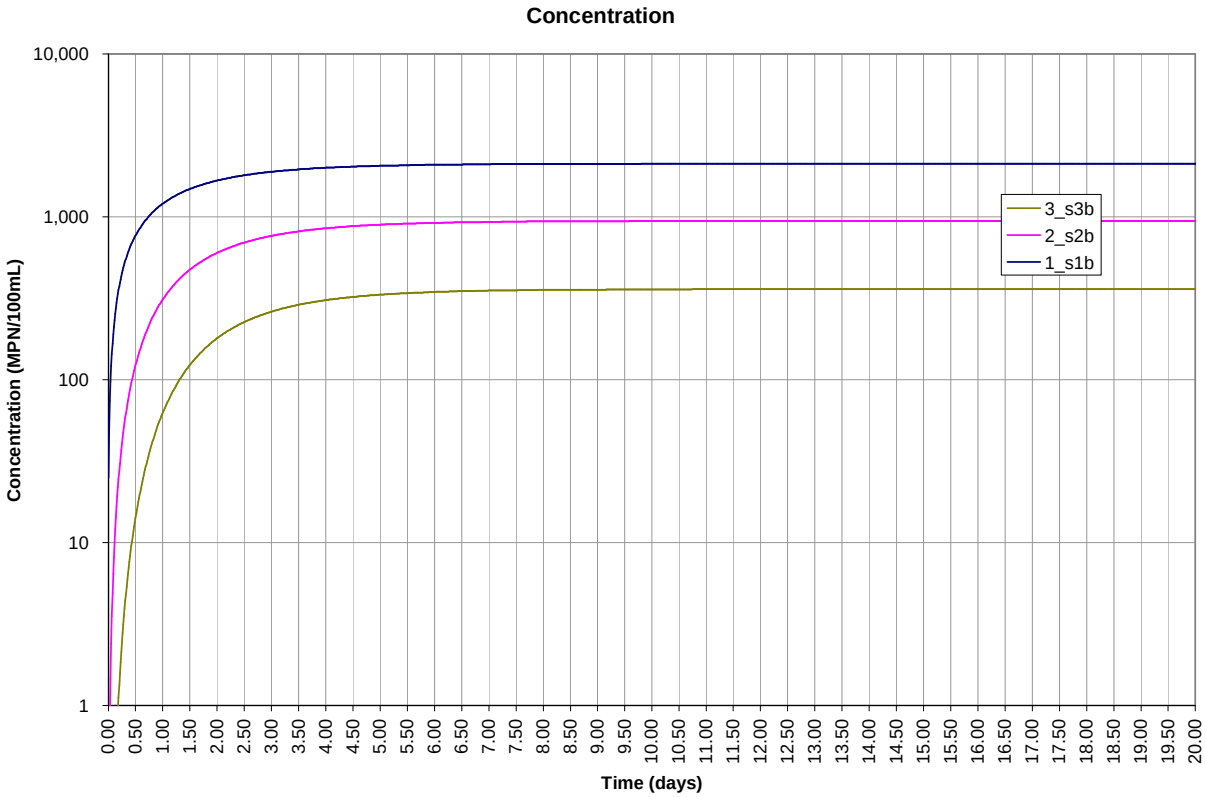


Figure E.65 Modeled Continuous Direct Discharge (septic) in the Blue Water Shores Canal

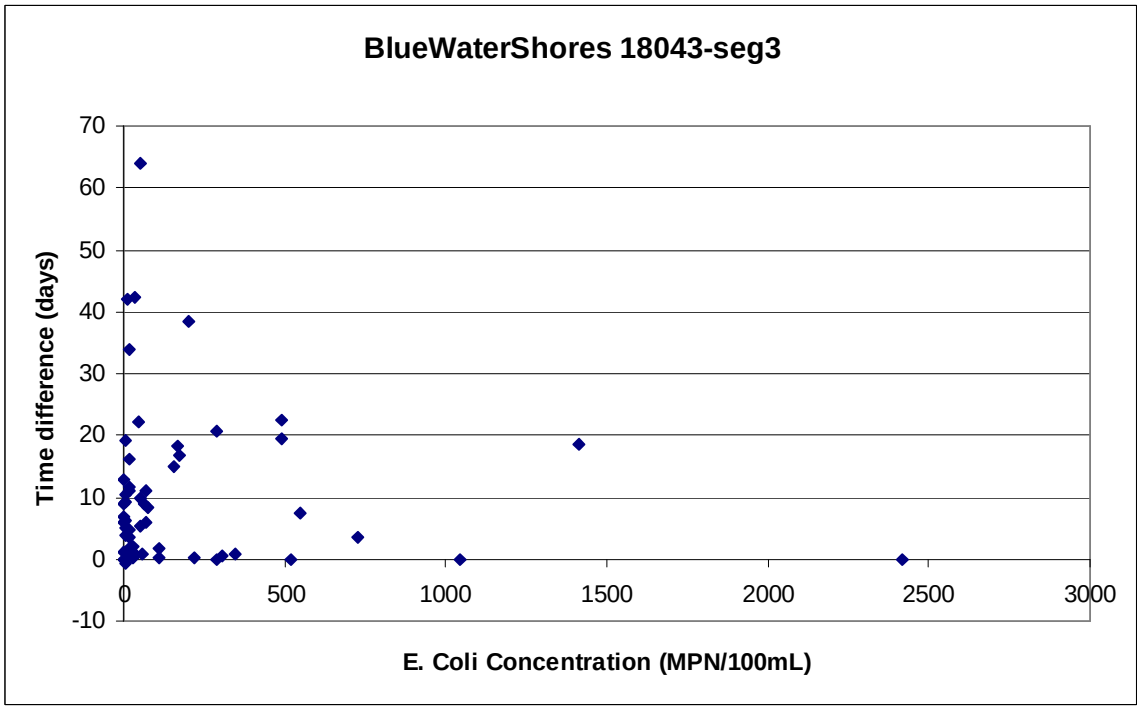


Figure E.66 Residual Plot for Station 18043 located within the Blue Water Shores Canal