Healthy Maine Beaches Program

Analysis of Water Quality Samples and Hydrodynamic Conditions for Goose Rocks Beach, Kennebunkport, and Goochs Beach, Kennebunk, Maine

June 1 – September 22, 2005

Peter A. Slovinsky and Stephen M. Dickson
Maine Geological Survey
22 State House Station
Augusta, ME 04333-0022

Introduction

This report presents an analysis of the relationship between enterococci scores, tides, and waves for the summer months of June, July, and August 2005 at Goochs Beach in Kennebunk, and Goose Rocks Beach in Kennebunkport (including additional data through September 22, 2005). The analysis was visual and qualitative rather than rigorously statistical due to the discontinuous time series of bacterial sampling and the lack of full bacteria scores (those above 200 col/100mL, or below 10 coll/100mL levels) for the analyses through the first part of summer.

Review of the data suggests several important insights into (a) the sampling protocol with respect to rising and falling tides, (b) the timing of high bacterial scores in relation to the fortnightly variation in tidal range, (c) how the duration of elevated levels is affected by mixing by waves, (d) where possible bacterial source areas are, and (e) that the beaches do not have the same source. The main findings are listed below.

Please refer to the attached Tables 1 and 2, and Figures 1-3. Tables 1 and 2 summarize enterococci scores and tidal conditions for the study period. Figure 1 shows the relationships between water quality sample enterococci scores (from volunteer data, in col/100mL), tidal stage (from NOAA NOS CO-OPS data, and wave conditions (from NOAA NDBC and GoMOOS buoys) for Goochs Beach for the months of June (Figure 1a), July (Figure 1b), and August (Figure 1c). Figure 2 (a, b, and c) shows the same relationships for Goose Rocks Beach in Kennebunkport, including sampling that occurred into September (Figure 2d). Figure 3 shows generalized results from a current study that the Maine Geological Survey completed during ebb tidal conditions of a spring tidal cycle in August, 2005.

Results and Discussion

The trends at Goochs Beach and Goose Rocks Beach are both similar and notably different. General findings are summarized below, while specific hypotheses are provided for each beach later in the report.

Influence of Tidal Stages: An analysis of the tidal stage (flooding versus ebbing) and bacteria levels was undertaken for both beaches. The timing of samples (flood or ebb) is indicated in Tables 1 and 2 and shown in Figures 1 and 2. Contrary to expectations, which were that the highest readings would be correlated with ebb tidal conditions (assuming the source of contamination were the rivers), the time of sampling with respect to high bacterial concentrations indicates that higher readings were recorded during flood tidal conditions.

Influence of Spring Tides: Spring tide events appear to correlate with higher counts of enterococci at both beaches, though this trend is not nearly as strong for Goochs Beach as it is for Goose Rocks Beach.

Wave Influence: It appears that the presence of higher waves decreased enterococci scores due to mixing of the water column at both beaches, except at the Little River and Batson River Inlets.

Sources of Pollution: Analysis of data indicates that it is likely that high enterococci scores at Goose Rocks Beach may relate to the non-point release of bacteria from coastal wetlands during times of spring tides. It appears that water quality issues at Goochs Beach may be related to human point sources (i.e., direct discharges) or some other type of human-controlled activity (i.e., management of seaweed).

We present some more specific results and observations, highlighted in bold, for each beach below.

Goochs Beach

Samples taken at KBK-01 (closer to the Kennebunk River) exhibited generally low enterococci scores (only 6% of samples taken exceeded 100 col/100mL), while samples at KBK-02 (farther west of the river) were much higher (see Table 1). At KBK-02, 26% of samples collected exceeded 100 col/100mL. It is important to note that 33% of samples collected during a *flood tide (F)* at KBK-02 had enterococci scores greater than 100 col/100mL, while only 8% of ebb tide (E) samples recorded high enterococci scores. ***This is interesting if the source of contamination is the Kennebunk River, and suggests that nearshore circulation may bring contaminants out of the river on an ebb tide, but contaminants only reach the beach on the flood tide.***

It also appears that high bacteria scores *loosely* coincided with times of spring tides during June and July (see Table 2 and Figures 1a-1b). However, enterococci scores dramatically decreased after the high July 19 levels (Figure 1c). A decline in enterococci scores over the summer at Goochs Beach, while they continued to rise at Goose Rocks Beach suggests that some type of human activity changed in late July in the Kennebunk River watershed or along adjacent shorelines. This divergence in trends suggests to us that contamination at Goochs Beach is, to a first approximation, not driven by tidal levels or wave action. ***Therefore, it appears that Goochs Beach contamination problems may be due to one or more point sources***.

Goose Rocks Beach

The overall trend at Goose Rocks Beach over the four months of study (June-September) strongly suggests that bacterial scores rise with increased tidal range. The largest tides (spring tides) peaked around the third week of June, July, and August. ***We noted that the level of bacteria rose remarkably during spring tides*** (see Figures 2a-d). This general trend occurred primarily when the tide height reached 10 feet (MLLW) or more, although there does not appear to be an absolute level above which scores rose to extreme levels. This pattern was most pronounced in July, August, and September, when the frequency of sampling increased to more than once per week.

Similar to Goochs Beach, it appears that the highest percentage of suspect water quality samples occurred when samples were collected on the ***flood rather than the ebb tide*** (see Tables 1 and 2). This was especially noted for site GR-1 (at the Little River), where 50% of samples collected during the flood tide resulted in enterococci scores greater than 100 col/100mL, while 30% of ebb tide samples revealed such high scores. Similarly, 28% of samples collected on the flood tide at GR-5 (at the Batson River) recorded high scores, while only 11% of ebb tide samples had similar results. Conversely, scores at GR-2 to GR-4 (sites along the open beach and not at the inlets), were somewhat mixed in terms of tidal dominance. This may indicate a similar working hypothesis as at Goochs Beach – that ebbing currents from the Little River are concentrated within the small channel and contaminants that may be originating from the marshes are not reaching the beach inlet sample site at GR-1until the tide has turned to flood, bringing the contaminants back to the beach. Thus, ***it is possible that site GR-1 is receiving contaminants from both the Batson and Little Rivers, as our current studies indicated that ebb currents of the Batson River are capable of reaching the Little River littoral cell*** **(see area 4 in Figure 3)*.*** Contaminants from the Batson River may be reaching the Little River cell just as the tide turns to flood, which brings them to the beach and inlet nearest the Little River.

Hydrodynamic conditions relating to wave height appear to dilute bacteria levels along the beach sample sites (GR-2 to GR-4). When wave heights (at the more exposed Portland and GoMOOS buoys) reached 3 to 4 feet, beach bacteria levels appeared to fall, while the inlet sample sites (Little River, GR-1, and Batson River, GR-5) remained, on average, much higher (see Figure 2b – July 26, and Figure 2c – August 23-24, and Figure 2d – September 20-22). This is most likely due to mixing of the water column by wave action, which is limited at the inlet sites. ***It appears that wave action dilutes the concentration of bacteria along Goose Rocks Beach at samples GR-2 through GR-4***. However, wave action does not seem to dilute the inlet concentrations (GR-1 and GR-5) as much as along the beach. ***This difference suggests that the Batson and Little Rivers are bacteria source areas rather than a beach or offshore source.***

Data suggests that contamination may persist a week with calm conditions after the spring tide. High bacteria scores were found at the end of June (29 and 30) when the highest spring tides had abated (Figure 2a). Data were not collected at the peak spring tides on June 24, so it remains unknown if the high scores began a week before the samples were taken or not. Based on the correlation of high bacteria scores with spring tides in July and August however (Figures 2b-c), it is possible that the scores were high around June 24, but simply not measured. If this assumption is valid, then it seems likely that ***high scores could have persisted for a week after the peak spring tides*** during a time when waves were calm (below 3 feet). This hypothesis suggests that ***swimmer advisories might be extended for several days after a high reading- during times of higher tides - if waves remain calm or there is no other source of mixing (such as a strong offshore wind) in Goosefare Bay.***

It appears that water quality along Goose Rocks Beach is better during neap tides. During neap tides (particularly when the range is less than 9 feet), bacteria scores were low (i.e., near June 15 and July 13 on Figures 2a and 2b). The first date coincided with stormy seas and wave heights of 6-7 feet. The second date had low counts with calm seas. These observations support the trend for ***lower bacterial scores during neap tides***. The August neap tide had low counts along the beach but elevated levels (up to 200 col/100 mL) at the inlets, suggesting that ***the Batson and Little Rivers were still a source all month long.*** Samples collected during the first part of September (9/1 to 9/14) were generally low, aside from one exceedence. These sample times corresponded with lower tidal heights (<10 ft) and, in general, higher wave heights (see Figure 2d).

At Goose Rocks Beach, the fact that the concentrations tend to peak during times of highest tides, rather than during neap tides suggests that ***bacteria come from a non-point source*** in the watersheds. If there were a point source, the bacteria scores should theoretically rise during neap tides when there is less dilution from seawater. Consequently, ***the source(s) of contamination may be in the upper reaches of the coastal and freshwater wetlands*** that are inundated by extreme tides.

Findings and Recommendations

Based on the qualitative analysis of the data presented in this report, we are able to make the following findings and recommendations:

Goochs Beach - Findings

- High enterococci scores may relate to point, rather than non-point, source(s) of bacteria
- Some type of human activity change that occurred after July 19 resulted in dramatically lower enterococci scores
- High enterococci scores do not appear to be tide-related

Goochs Beach - Recommendations

- Review what type(s) of activities (i.e., direct discharges, seaweed management, etc.) may have changed around July 19 in order to possibly determine sources of bacteria

Goose Rocks Beach – Findings

- High enterococci scores may relate to non-point, rather than point, sources of bacteria
- High enterococci scores relate to higher tidal conditions, especially spring tides
- Enterococci scores appear to be controlled by wave mixing during times of higher wave heights, especially along the beach sample sites (GR-2 to GR-4)
- Consistently high enterococci scores at the inlet sites (GR-1 and GR-5), even in higher wave conditions, indicates that the river(s) appear to be the source(s) of bacteria
- Because enterococci scores appear to spike at times of spring tide, it appears that bacteria are released once tidal waters reach a certain elevation

Goose Rocks Beach – Recommendations

- Consider using the predictive capability of forecasted spring tides to post swim advisories *in advance* of higher tidal conditions, *especially if low wave conditions are expected*
- Continue, at a minimum, weekly sampling at GR-1 to GR-5 through the month of October in order to capture an additional spring tidal cycle during a time of decreased beach usage by humans. Sampling of several-times a week is preferred.
- Conduct an additional Acoustic Doppler Current Profiler (ADCP) survey during *flood tide* conditions on the next spring tidal cycle (October 17-19) in order to confirm or disprove the hypothesis that return flood currents may be concentrating bacteria at site GR-1 (Little River)

Date	KBK-01	KBK-02	GR-1	GR-2	GR-3	GR-4	GR-5
6/1	E	E	E	E	E	E	E
6/3		F					
6/8			F	F	F	F	F
6/15	E	E	E	E	E	E	E
6/22		F					F
6/23		F					
6/29	E	E	E	E	E	E	E
6/30			E	E	E		
7/3							
7/6	F	F	F	F	F	F	F
7/7			E				
7/12							
7/13	E	E	E	E	E	E	E
7/19	F	F	F	F	F	F	F
7/21	F	F	F	F	F	F	F
7/22	F	F					
7/26	E	E	E	E	E	E	E
7/27			E	E	E	E	E
7/28			E	E	E	E	E
7/29			E	E	E	E	E
8/1			F	F	F	F	F
8/2	F	F	F	F	F	F	F
8/3	F	F	F	F	F	F	F
8/4			F	F	F	F	F
8/5			F	F	F	F	F
8/8			F	F	F	F	F
8/9	F	F	F	F	F	F	F
8/10			F	F	F	F	F
8/11			E	E	E	E	E
8/12			E	E	E	E	E
8/15			E	E	E	E	E
8/16	E	E	E	E	E	E	E
8/17			E	E	E	E	E
8/18			F	F	F	F	F
8/19			F	F	F	F	F
8/22			F	F	F	F	F
8/23	F	F	F	F	F	F	F
8/24			F	F	F	F	F
8/25	F	F	F	F	F	F	F
8/26			E	E	E	E	E
8/29			E	E	E	E	E
8/30	E	E	E	E	E	E	E
8/31			E	E	E	E	E
9/1			F	F	F	F	F
9/2			F	F	F	F	F
9/7			F	F	F	F	F
9/13			E	E	E	E	E
9/20			F	F	F	F	F
9/21			F	F	F	F	F
9/22			F	F	F	F	F
Total	16	19	44	43	43	42	43
Total E	7	7	20	19	19	18	18
Total F	9	12	24	24	24	24	25
Total	1	5	18	7	5	8	9
%	6	26	41	16	12	19	21
%F>100 ^	11	33	50	17	17	21	28
%E>100 #	0	8	30	16	5	17	11

Table 1. Table of data showing: date of water quality sample collection, tidal stage (ebb (E) or flood (F), and enterococci scores exceeding 100 col/100 mL. Summary information is provided at the bottom of the table.

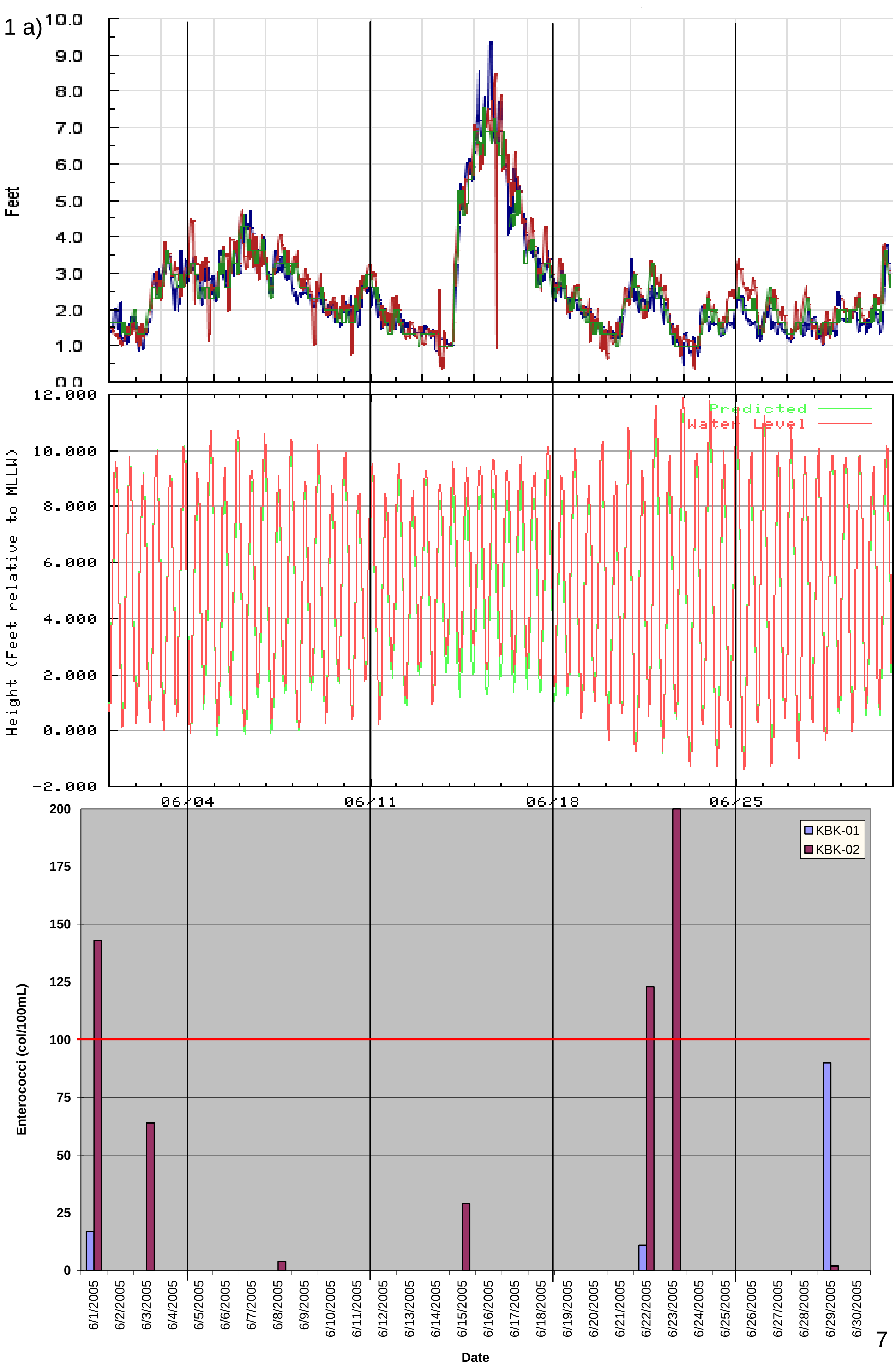
Table 2 (following page). Table of data showing dates of sampling, actual enterococci scores (col/100mL), averages for each beach on each date, and tidal stages, including ebb or flood, and spring tidal cycles.

Date	KBK-01	KBK-02	KBK-AVG	GR-1	GR-2	GR-3	GR-4	GR-5	GR-AVG	TIDE ST	SPRING~
6/1	17	143	**80**	128	52	48	20	20	**54**	E	
6/3		64	**64**							F	
6/8	0	4	**2**	19	16	25	6	62	**26**	F	
6/15	0	29	**15**	45	18	20	5	34	**24**	E	
6/22	11	123	**67**	19	4	6	83	113	**45**	F	S
6/23		200	**200**							F	S
6/29	90	2	**46**	98	200	66	200	4	**114**	E	S
6/30				200	200	200			**200**	E	
7/3		3	**3**							E	
7/6	9	200	**105**	200	44	51	59	51	**81**	F	
7/7				2					**2**	F	
7/12		94	**94**							E	
7/13	50	7	**29**	97	32	24	8	68	**46**	E	
7/19	151	199	**175**	192	246	188	200	159	**197**	F	S
7/21	60	45	**53**	201	22	80	201	48	**110**	F	S
7/22	16	42	**29**							F	S
7/26	10	42	**26**	200	0	4	13	200	**83**	E	S
7/27				52	2	1	0	37	**18**	E	S
7/28				16	25	4	14	60	**24**	E	
7/29				16	22	12	183	9	**48**	E	
8/1				31	59	15	72	7	**37**	F	
8/2	16	66	**41**	14	12	12	2	10	**10**	F	
8/3	10	11	**11**	20	10	10	10	10	**12**	F	
8/4				56	33	66	10	34	**40**	F	
8/5				117	218	46	22	112	**103**	F	
8/8				42	11	12	10	48	**25**	F	
8/9	10	10	**10**	201	10	10	29	25	**55**	F	
8/10				29	10	10	27	12	**18**	F	
8/11				103	25	92	83	45	**70**	E	
8/12				201	91	56	201	201	**150**	E	
8/15				31	31	41	10	20	**27**	E	
8/16	41	31	**36**	30	10	31	10	10	**18**	E	S
8/17				332	41	20	74	40	**101**	E	S
8/18				108	318	160	20	10	**123**	F	S
8/19				315	41	109	408	63	**187**	F	S
8/22				323	216	201	30	884	**331**	F	S
8/23	10	10	**10**	311	20	10	10	341	**138**	F	S
8/24				259	10	10	10	368	**131**	F	S
8/25	86	20	**53**	20	10	10	10	52	**20**	F	
8/26				10	20	52	10	10	**20**	E	
8/29				10	10	10	10	20	**12**	E	
8/30	20	10	**15**	30	20	31	10	10	**20**	E	
8/31				31	135	52	20	20	**52**	E	
9/1				31	52	41	107	52	**57**	F	
9/2				31	52	52	10	31	**35**	F	
9/7				31	10	10	10	20	**16**	F	
9/13				10	10	10	10	10	**10**	E	
9/20				417	41	20	142	72	**138**	F	S
9/21				110	10	10	20	160	**62**	F	S
9/22				75	31	10	10	10	**27**	F	S
AVG	**34**	**62**		**107**	**56**	**44**	**56**	**83**			
SD	**40**	**68**		**109**	**77**	**52**	**84**	**150**			
MIN	**0**	**2**		**2**	**0**	**1**	**0**	**4**			
MAX	**151**	**200**		**417**	**318**	**201**	**408**	**884**			

~ greater than 10 ft spring tide — x>100 100mL

note: many readings were capped at 200 col/100mL or less than 10 col/100 mL

1 a)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6.0
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1.0
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12.000
10.000
8.000
6.000
4.000
2.000
0.000
-2.000
Predicted
Water Level
06/04
06/11
06/18
06/25
Enterococci (col/100mL)
200
175
150
125
100
75
50
25
0
KBK-01
KBK-02
6/1/2005
6/2/2005
6/3/2005
6/4/2005
6/5/2005
6/6/2005
6/7/2005
6/8/2005
6/9/2005
6/10/2005
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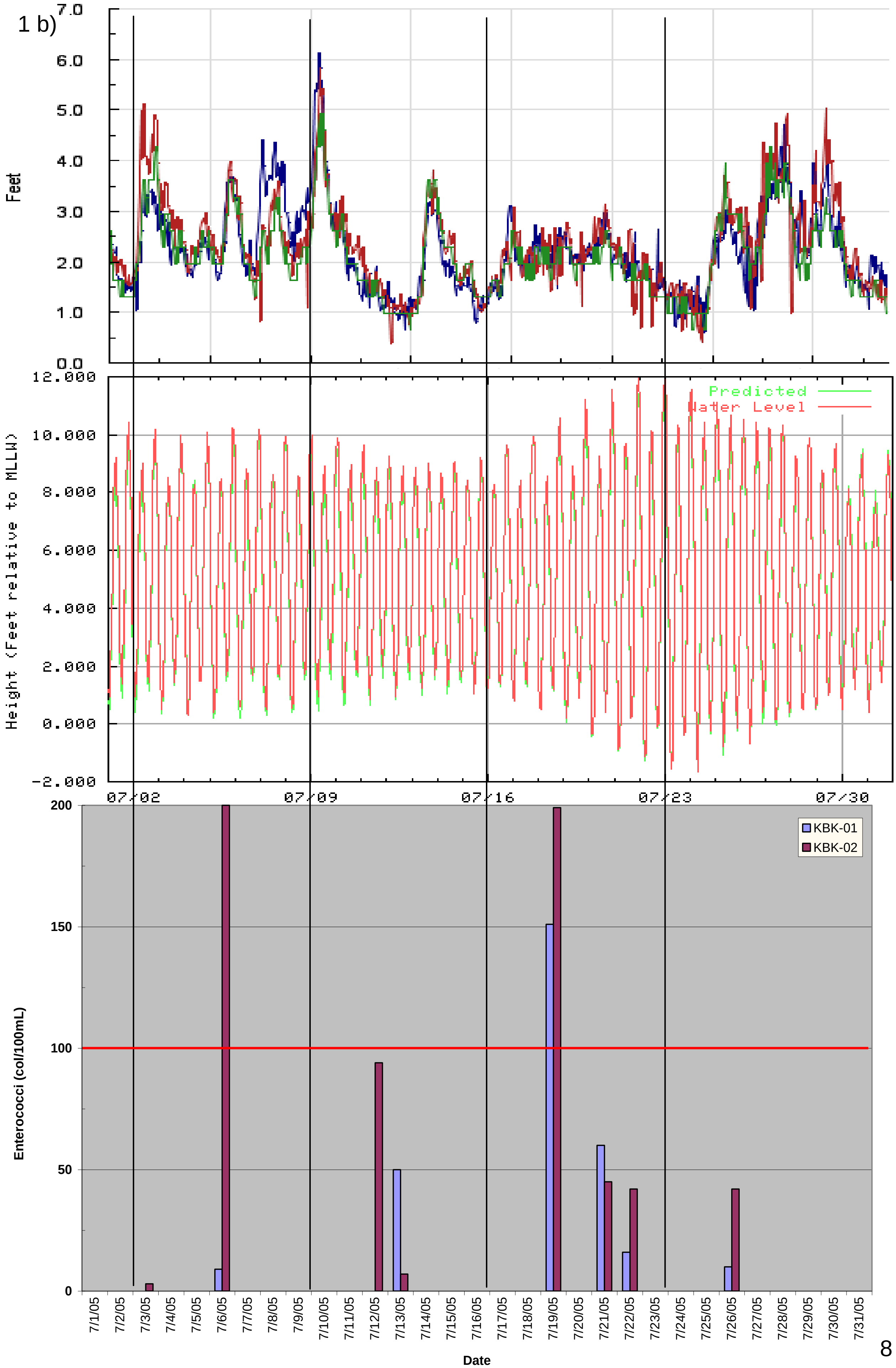
6/30/2005
Date

1 b)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Feet
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2.000
0.000
-2.000
Height (Feet relative to MLLW)
Predicted
Water Level
07/02
07/09
07/16
07/23
07/30
200
150
100
50
0
Enterococci (col/100mL)
KBK-01
KBK-02
7/1/05
7/2/05
7/3/05
7/4/05
7/5/05
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7/7/05
7/8/05
7/9/05
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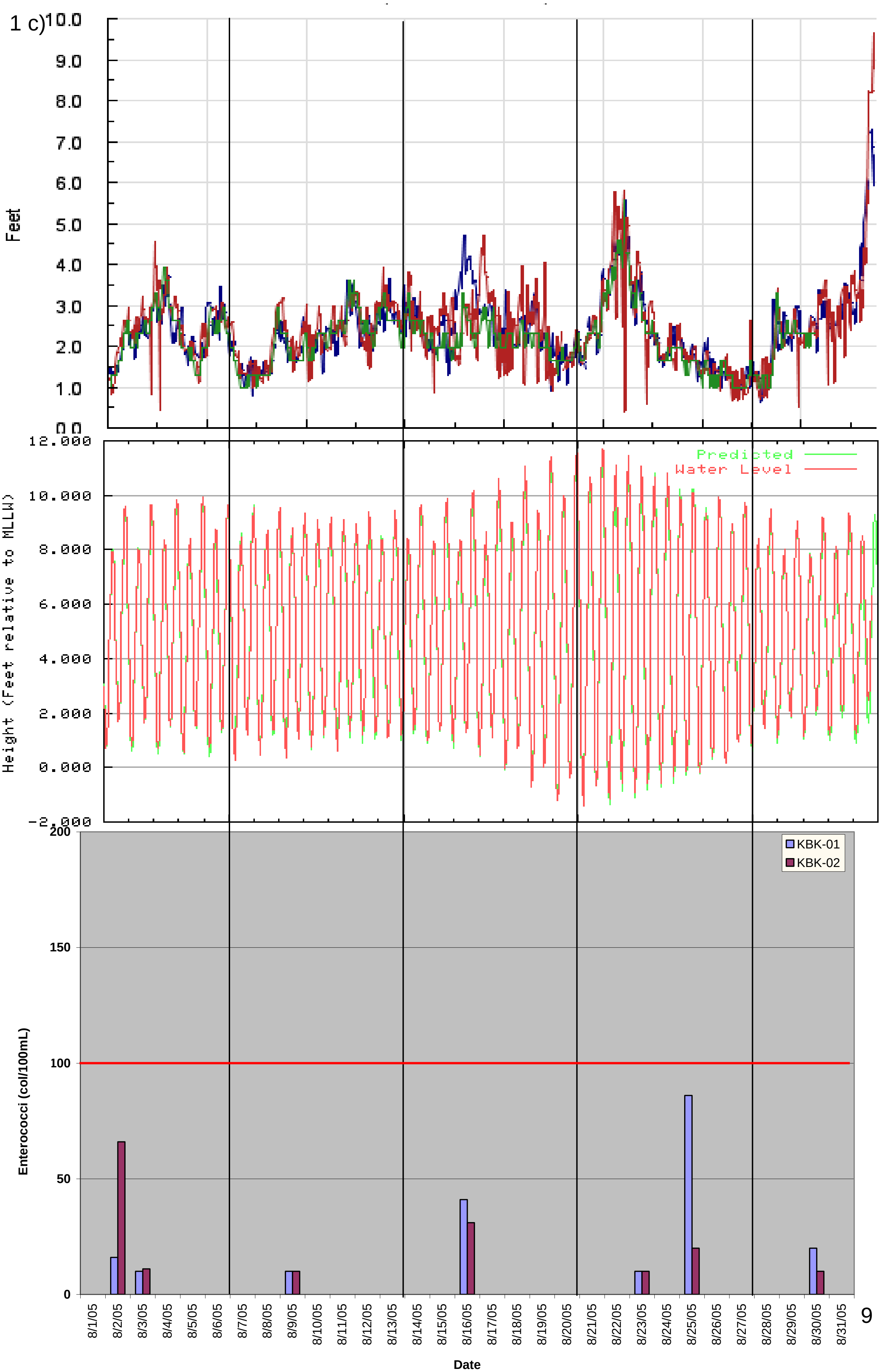
7/31/05
Date

1 c)



Feet
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1.0
0.0
Height (Feet relative to MLLW)
12.000
10.000
8.000
6.000
4.000
2.000
0.000
-2.000
Predicted
Water Level
Enterococci (col/100mL)
200
150
100
50
0
KBK-01
KBK-02
8/1/05
8/2/05
8/3/05
8/4/05
8/5/05
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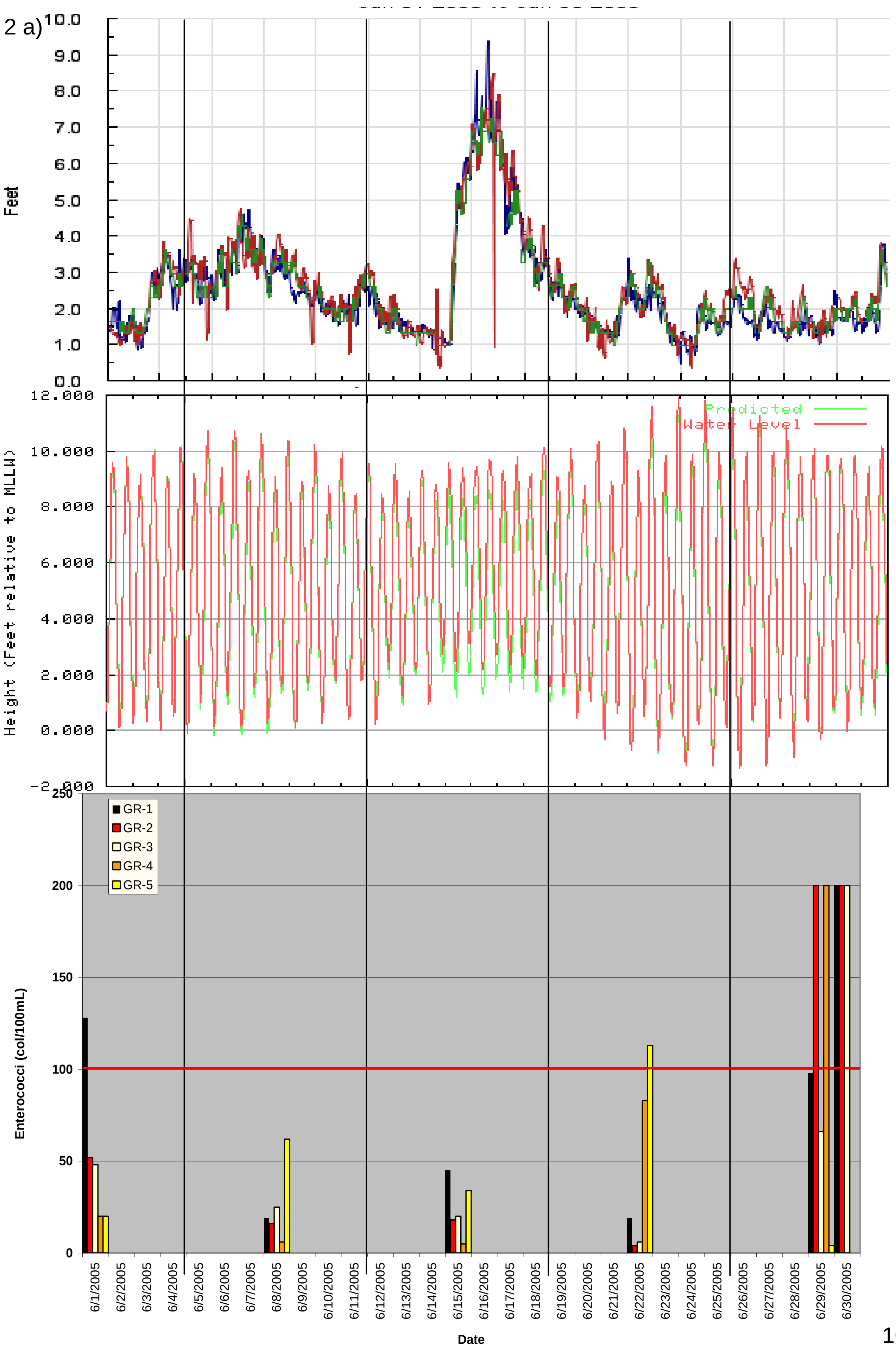
8/31/05
Date

2 a)


Feet
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6.0
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4.0
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1.0
0.0
Height (Feet relative to MLLW)
12.000
10.000
8.000
6.000
4.000
2.000
0.000
-2.000
Predicted
Water Level
Enterococci (col/100mL)
250
200
150
100
50
0
GR-1
GR-2
GR-3
GR-4
GR-5
6/1/2005
6/2/2005
6/3/2005
6/4/2005
6/5/2005
6/6/2005
6/7/2005
6/8/2005
6/9/2005
6/10/2005
6/11/2005
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6/23/2005
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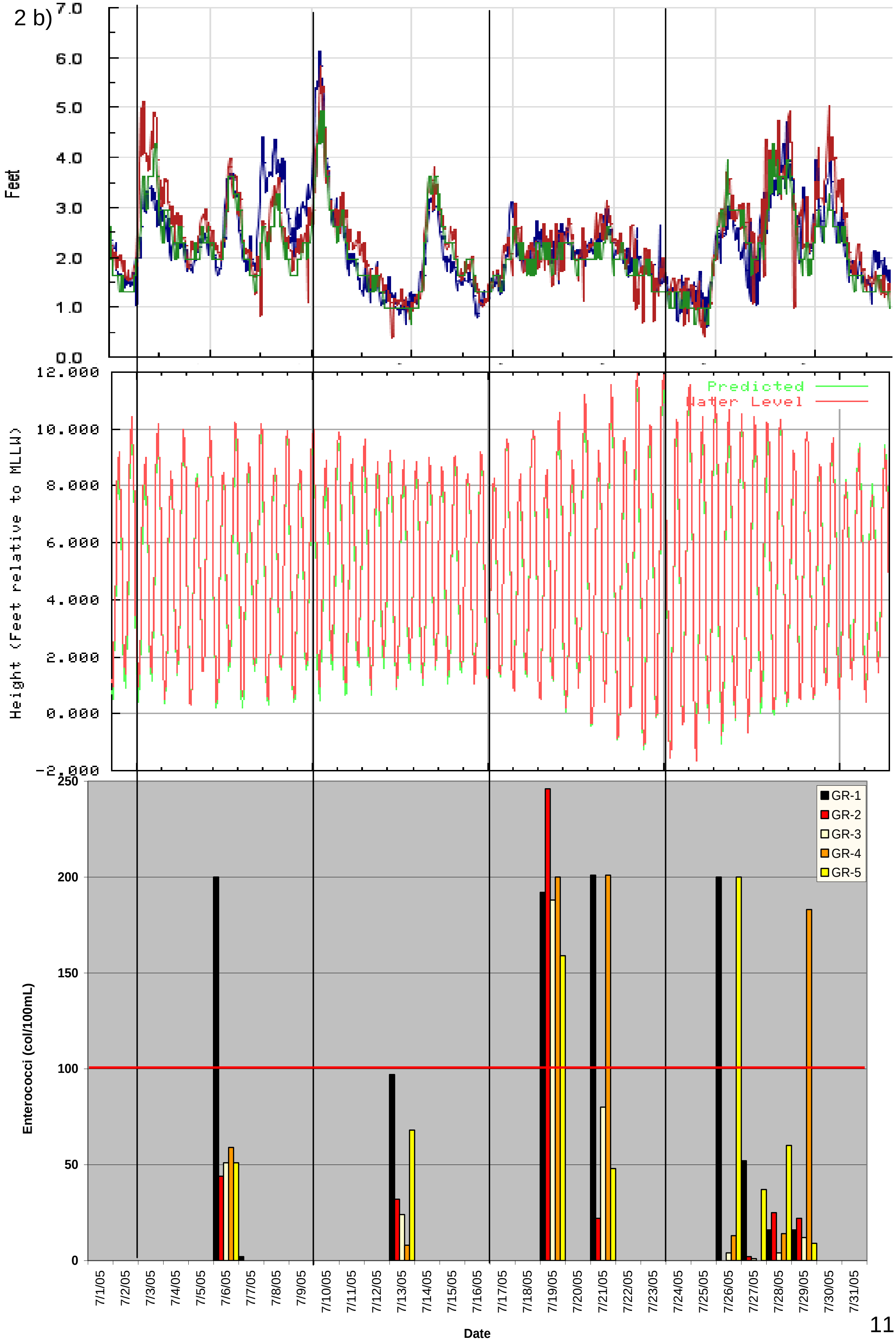
6/27/2005
6/28/2005
6/29/2005
6/30/2005
Date

2 b)



Feet
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Height (Feet relative to MLLW)
12.000
10.000
8.000
6.000
4.000
2.000
0.000
-2.000
Predicted
Water Level
Enterococci (col/100mL)
250
200
150
100
50
0
GR-1
GR-2
GR-3
GR-4
GR-5
7/1/05
7/2/05
7/3/05
7/4/05
7/5/05
7/6/05
7/7/05
7/8/05
7/9/05
7/10/05
7/11/05
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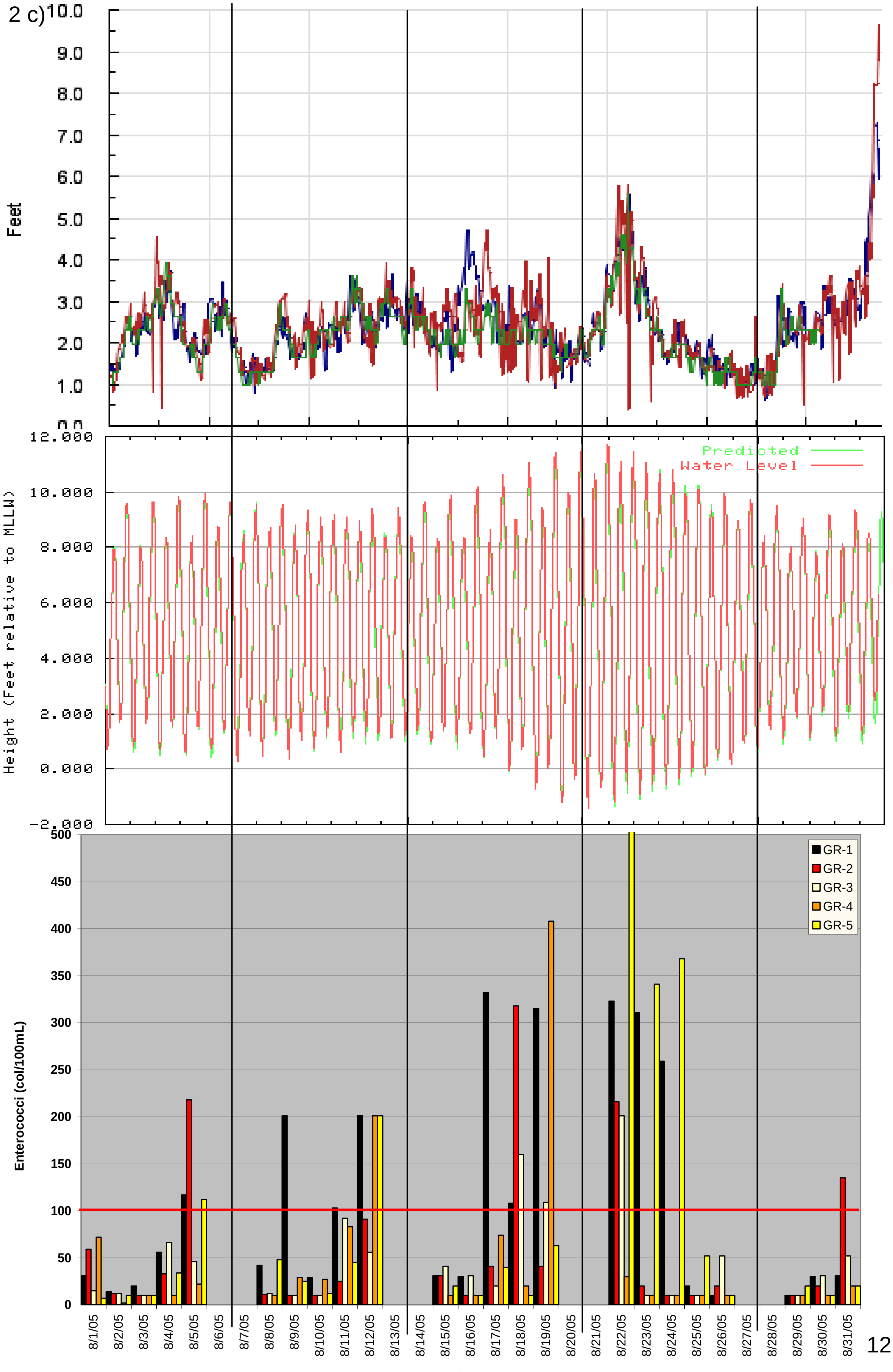
7/31/05
Date

2 c)



Feet
10.0
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Height (Feet relative to MLLW)
12.000
10.000
8.000
6.000
4.000
2.000
0.000
-2.000
Predicted
Water Level
Enterococci (col/100mL)
500
450
400
350
300
250
200
150
100
50
0
GR-1
GR-2
GR-3
GR-4
GR-5
8/1/05
8/2/05
8/3/05
8/4/05
8/5/05
8/6/05
8/7/05
8/8/05
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8/10/05
8/11/05
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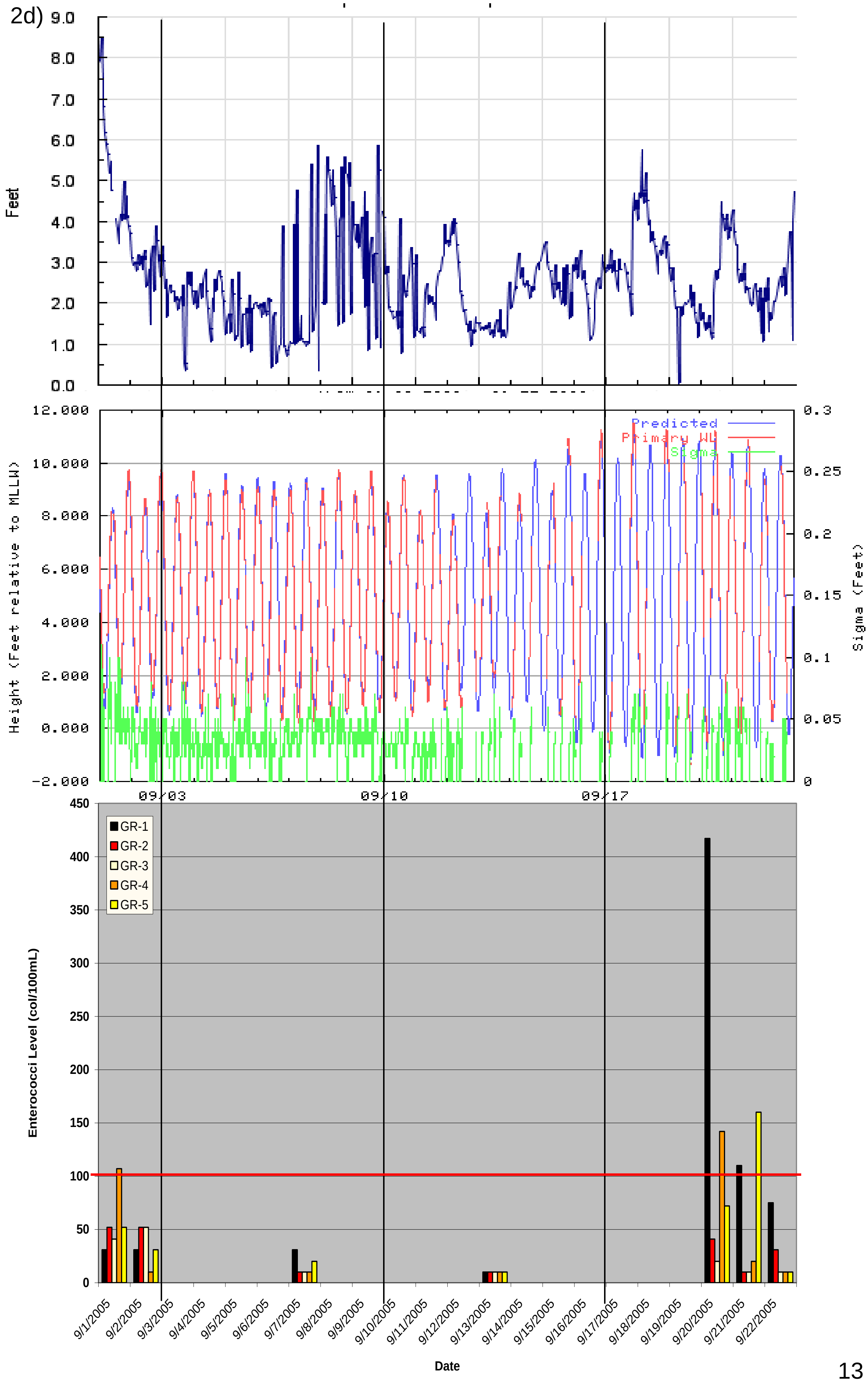
8/26/05
8/27/05
8/28/05
8/29/05
8/30/05
8/31/05
Date

2d)


Feet
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0
0.0
Height (Feet relative to MLLW)
Sigma (Feet)
Predicted
Primary WL
Sigma
09/03
09/10
09/17
GR-1
GR-2
GR-3
GR-4
GR-5
Enterococci Level (col/100mL)
9/1/2005
9/2/2005
9/3/2005
9/4/2005
9/5/2005
9/6/2005
9/7/2005
9/8/2005
9/9/2005
9/10/2005
9/11/2005
9/12/2005
9/13/2005
9/14/2005
9/15/2005
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9/17/2005
9/18/2005
9/19/2005
9/20/2005
9/21/2005
9/22/2005
Date

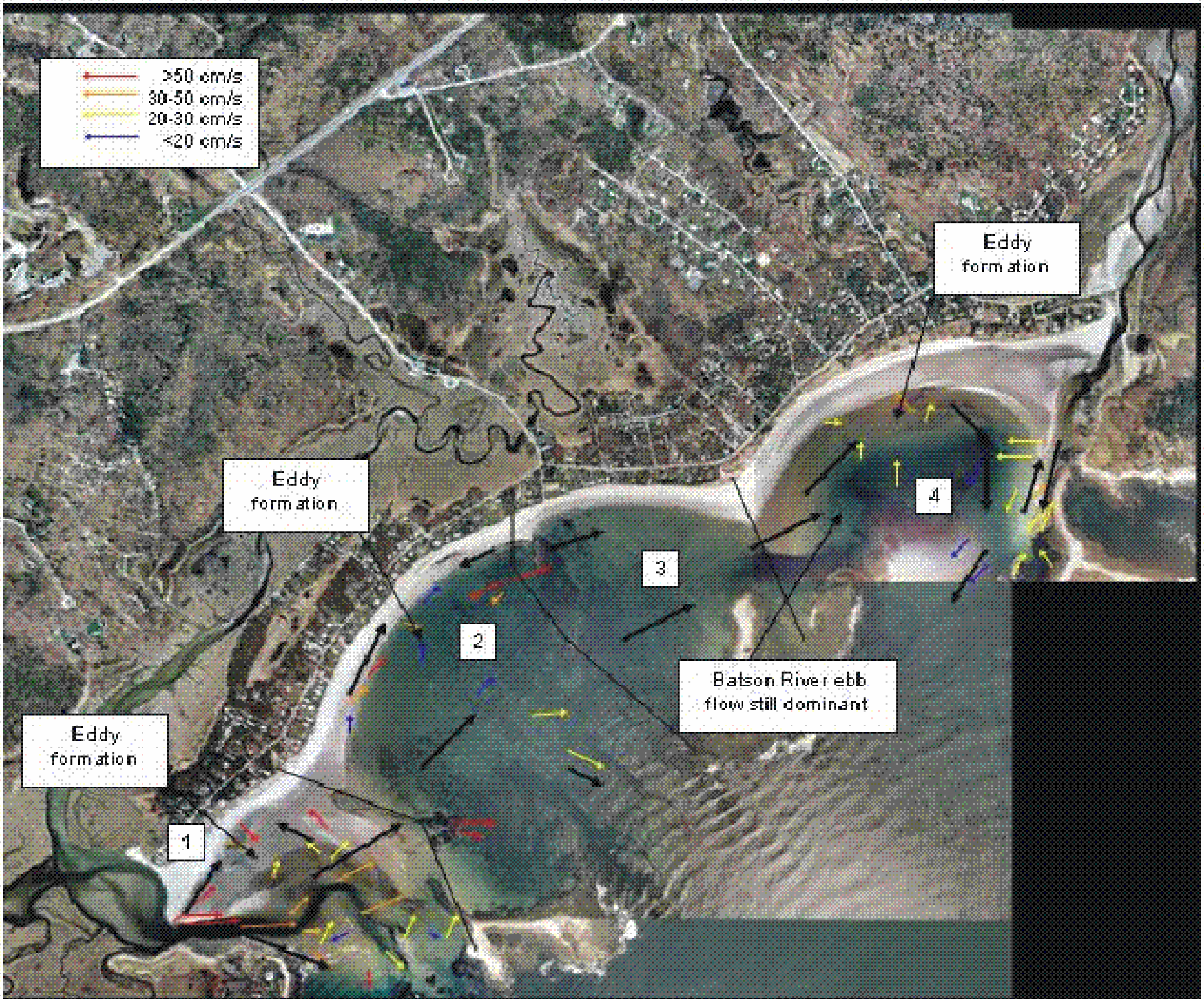

Figure 3. Generalized results of MGS ADCP current study conducted on August 19, 2005 during ebb tidal conditions at start of spring tidal cycle. Black arrows indicate general flow pattern, while colored arrows indicate actual data (see legend for speeds). Study area was divided into 4 littoral cells (labeled 1-4) based on current patterns and morphologic characteristics. 50 cm/s is approximately half a nautical mile per hour. Photograph from MEGIS.