Attachment A: Report on Environmental Conditions for Walleye in Cherry Creek Reservoir, Prepared by Dr. Brett Johnson

ENVIRONMENTAL CONDITIONS FOR WALLEYE IN CHERRY CREEK RESERVOIR

Prepared by
Dr. Brett M Johnson

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INTRODUCTION

The Cherry Creek Basin Water Quality Authority (CCBWQA) installed a reservoir destratification system ("aerator") at Cherry Creek Reservoir (CCR) in 2008. Low dissolved oxygen conditions were thought to have exacerbated nutrient loading from the sediment and promoted nuisance algal blooms. The aerator was designed to reduce stratification, internal nutrient loading and bloom conditions for cyanobacteria (CCBWQA 2013). Apparent changes in chlorophyll concentration after the aerator was installed prompted the CCBWQA to seek a better understanding of the effects of the aerator on the food web and water quality in the reservoir. In 2014 CCBWQA contracted with Hydros Consulting to develop a water quality model and analyze food web data. An important component of the contract was information useful to maintaining a high quality walleye (*Sander vitreus*) fishery in the reservoir. This report presents analyses and recommendations to that end.

METHODS

I reviewed the scientific literature on walleye and gizzard shad population biology, as well as studies that examined interactions between the species in a food web context. Several empirical data sets from CCR were available. I used water quality and plankton data collected by CCBWQA. Colorado Division of Parks and Wildlife provided fish survey data (1981-2013). Fish survey gear included gill nets, trap nets and boat electrofishing and different combinations of gear were deployed across seasons and years. The CPW biologist in charge of surveys at CCR changed in 2004 when the current biologist started in that post; thus, it is possible that survey objectives and protocols changed at that time. Colorado Division of Parks and Wildlife also provided fish stocking data (1973-2013).

I examined temperature and dissolved oxygen profiles measured seasonally at multiple sites in Cherry Creek Reservoir during 1992-2013. For each year of data I determined the maximum temperature of the reservoir, the maximum depth at which ≥4.0 mg/L (a threshold for fish) of oxygen was available, and the minimum dissolved oxygen concentration measured at 1 m depth each year. I also examined the rate of spring warming (April and May), which is an important predictor of spawning timing and larval development in walleyes, gizzard shad and many other fish species. I collated data on the temperature of the reservoir (at site CCR2) measured at 1-m depth during April and May of 1996-2012 (1995 was anomalous), and fit a linear regression to temperature as a function of date.

Zooplankton monitoring data were available for 1995-2001 and 2011-2013. Sampling and lab analysis of macrozooplankton samples differed slightly during the period (C. Wolf, GEI, personal communication, 7/23/14). During 1996-2001 zooplankton were all sampled with a Schindler-Patalas trap with 63-µm bucket but the types of samples changed. In 1996-1998 samples were collected at a depth equal to one half the Secchi depth. During 1999-2001 samples were composited by site and three discrete sampling depths: surface, one half Secchi depth, and two times Secchi depth. All these samples were analyzed by Chadwick & Associates. From 2011-2013 zooplankton were sampled with a Student plankton net with 80-µm mesh and 203-mm diameter opening. Each sample in the database was a composite of three sites with 6-m vertical tows at CCR-1 and CCR-2 and 4-m vertical tows from site CCR-3. All these samples were analyzed by Water's Edge Scientific.

I examined the times series of densities (number per liter) of major macrozooplankton taxa measured during 1999-2013 when samples from sites were composited. Rotifers and immature life stages of other taxa were excluded, partly because not enough was known about sampling net efficiency for small plankton, and because these forms are less important to fish. I classified the remaining organisms (all exploited by planktivorous fish) as 1) *Bosmina* spp., 2) calanoid copepods, 3) cyclopoid copepods, and 4) *Daphnia* spp. (*D. lumholtzi* were rare, and were analyzed separately). The last group (*Daphnia*) is considered to be the most effective grazers on phytoplankton; they can feed on a wider range of phytoplankton taxa, and they recycle nutrients less than smaller-bodied forms. Absolute and relative abundance of these taxa were examined by year, and by sampling date. I also computed mean lakewide density of *Daphnia* in spring, when young walleye and shad are mainly planktivorous, as an indicator of food availability. This metric also approximated spring grazing intensity by *Daphnia* each year, when many lakes exhibit a grazing induced clearwater phase.

Fish body condition was estimated by computing Relative Weight (W_r; Pope and Kruse 2007). Walleye were grouped into size classes corresponding to Proportional Size Distribution (PSD; Neumann et al. 2012) length categories: <250 mm (juveniles), 250-379 mm (stock size), 380-509 mm (quality size), 510-629 mm (preferred size), 630-759 mm (memorable size), and >759 mm (trophy size). In the first analysis pass all survey data were aggregated and average W_r (±SD) was computed each year. Next, to control for seasonal differences in when surveys were conducted, only data from August and September were used to compute W_r.

Fish growth data were not available so I used the Petersen length-frequency method (Quist et al. 2012) to infer age-growth and evaluate year class strength. I examined length-frequency histograms of walleye collected in surveys completed in September to estimate the size of age-0 walleye each year. A rough estimate of GSD growth was determined from modes of length-frequency histograms in two periods: 1995-2006, pre-aerator and 2008-2013, post-aerator. These growth rate estimates are approximate because of the problem with differential sampling gear and protocols among years.

RESULTS AND DISCUSSION

Fish Life History Characteristics

Walleye are a piscivorous sport fish prized by anglers worldwide. Walleye are classified as coolwater fishes, with an optimum temperature of 22-24°C (Table 1) (McMahon et al. 1984; Hanson et al. 1997). As in other fishes, thermal preference is affected by many things, including food availability. At high food availability walleye can grow well at higher temperatures than they would with less food. Walleye are reported to tolerate dissolved oxygen levels of about 2 mg/L for short periods but only thrive at dissolved oxygen ≥4.0 mg/L (McMahon et al. 1984). Walleye begin spawning at about 8°C, and eggs hatch approximately two weeks after being laid (Scott and Crossman 1973). The fry begin feeding before the yolk sac is fully absorbed, and they typically move to pelagic areas within two weeks of hatching. Walleye fry often compete with other species of fish for zooplankton (Colby et al. 1979) until suitably sized prey fish become available. Larval walleye are known to feed on larval prey fish within days of hatching, if the prey are below the walleye's gape limit (Donovan et al. 1997). Spring warming, adult female body condition in the fall prior to spawning, and the abundance of prey fish such as gizzard shad all have been shown to affect walleye reproductive success (Madenjian et al. 1996; Zhao et al. 2013). It appears that in colder climates (e.g., upper Midwest, Northeast U.S.), size of age-0 walleye in fall affects overwinter survival (Forney 1976; Madenjian et al. 1991). In warmer climates first year growth seems less important to subsequent survival (Donovan et al. 1997).

The gizzard shad (*Dorosoma cepedianum*) is an omnivorous prey fish species that is widely distributed across the United States. They feed on zooplankton in open water, but they also forage on the substrate in shallow water, consuming detritus (Williamson and Nelson 1985; Yako et al. 1996; De Brabandere et al. 2009). Larval gizzard shad are almost exclusively zooplanktivorous (Yako et al. 1996), but they quickly develop morphological features that allow them to feed on sediment detritus (Mundahl and Wissing 1987). Gizzard shad can dominate reservoir food webs because they can deplete zooplankton, thereby reducing food for other planktivorous fish. The gizzard shad's omnivorous feeding allows them to persist even when zooplankton resources are too low for other species of fish to survive. Gizzard shad also translocate sediment nutrients to the water column (Vanni et al. 2005). These characteristics highlight the important food web and water quality effects of this keystone species.

Spawning of gizzard shad is initiated when spring water temperature reaches about 16°C (Williamson and Nelson 1985), but spawning is asynchronous and may occur over an extended period of the spring and summer. Incubation is temperature dependent: 105 h at 16°C and 32 h at 23°C. Gizzard shad are highly fecund and are thus prone to overpopulation. Gizzard shad are sensitive to rapid temperature change and massive die-offs are also common (Michaletz 2010). Age-0 fish are most prone to temperature-related mortality. Unusually cold winters can result in high mortality of all age classes. Adult shad prefer water temperatures of 22-29 °C, and avoid dissolved oxygen levels below 2.0 mg/L. Gizzard shad are very tolerant of turbidity and eutrophication.

Temperature and oxygen

Cherry Creek Reservoir gets warmer than is optimal for walleye in most summers (Figure 1A), and is within the preferred temperature range of gizzard shad. Because the reservoir is often nearly isothermal, regardless of operation of the aeration system, there is no thermal refuge in the main body of the reservoir when surface temperatures exceed the walleye's preferred temperature. Sufficient dissolved oxygen was always available for fish in the upper half of the water column (Figure 1B; note that oxygen data from 2009 are not considered reliable and have been omitted). The minimum dissolved oxygen measured near the surface was always above the fish tolerance threshold (~4 mg/L). With the exception of very low water temperatures in 1995, interannual differences in rate of spring warming were small. A linear regression of water temperature vs. date with all years (1996-2013) combined produced a good fit to the data (Figure 2; r^2=0.82).

Macrozooplankton

I do not think the change in sampling gear and mesh size during 1999-2001 vs. 2011-2013 had a significant effect on interpretations of the time series. Schindler-Patalas samplers may be more efficient than the Student net which could result in somewhat higher density estimates with the former gear. Zooplankton taxonomic data from 2001 appeared anomalous in that a large number of unusual species were recorded in the database, but never observed in other years. For example, the cyclopoid copepods *Acanthocyclops vernalis, Microcyclops varicans, Orthocyclops modestus, and Paracyclops fimbriatus poppei,* appeared only in 2001. However, these unusual data probably did not affect my analyses since I aggregated zooplankton taxa into major groups, including "cyclopoid copepods". The lack of data immediately before and after installation of the aerators is more problematic because it makes inference about aerator effects on zooplankton difficult.

In general, the macrozooplankton species assemblage was comparable to others I've seen in Colorado reservoirs. Except for daphnids, the primary zooplankton groups were dominated by a few species. The Bosmina group was primarily represented by *B. longirostris,* which is commonly found in many other Colorado reservoirs (Martinez et al. 2010). Several other species of small cladocerans were detected only in 2001 (e.g., *Echinisco rosea*, *Eubosmina* sp., *Moina* sp.). Calanoid copepods consisted of *Leptodiaptomus* sp. and *Skistodiaptomus* sp. , and Cyclopoid copepods were mainly *Diacyclops bicuspidatus thomasi* and *Mesocyclops edax*. Seven species of *Daphnia* were observed: *D. ambigua, D. galeata mendotae, D. lumholtzi, D. parvula, D. pulex/pulicaria, D. rosea.* and *D. schoedleri.* The *Daphnia* assemblage was more diverse than most of the coldwater reservoirs I've worked on in Colorado, but not unexpected given the elevation and productivity at CCR.

Total macrozooplankton density was similar across years, with the exception of 2011, when most taxa were more abundant than in other years (Figure 3). Seasonal total zooplankton density during April-September was not significantly different (p = 0.39) between pre- and post-aerator years. In all years but 2000, *Bosmina* was the dominant group. Since 2000 calanoids dominated the copepod groups, with cyclopoids more abundant in 1999-2001. Some studies have shown that abundance of both cyclopoids and *Daphnia* increase with system productivity, but not calanoids (Thorp and Covich 2010). Calanoids sometimes dominate when food quality or density are low or food density is very high (Thorp and Covich 2010). In general, relative and absolute abundance of calanoids were higher in the years after the aerators were installed, but power to detect statistical differences was low. Further, the biological significance of this pattern is difficult to assess since interactions among copepod groups and *Daphnia* are a complex mix of predation and competition effects (Soto and Hurlbert 1991).

The density of *Daphnia* spp. during April-September was variable across years but it was not possible to link changes in *Daphnia* to fish populations because fish abundance estimates were not available. There were surprisingly high densities (> 20 daphnids per liter) measured in some months of 1999, 2011-2013 (Figure 4), but overall 2011 had much higher zooplankton densities than any other year. The mean density of zooplankton in April-May was also highly variable (Table 2), and 2011 was again highest. Excluding 2011, *Daphnia* density during April-May was about 3.5 daphnids/L, which seems low compared to *Daphnia* observed in less productive reservoirs, such as Granby and Blue Mesa reservoirs (Martinez et al. 2010).

In the aerator years relatively high densities of *Daphnia* were observed in July and August, which is surprising since *Daphnia* numbers in other systems are often lowest in summer when food may be limiting and predation intensity from fish is high. It is highly speculative, but the pattern of *Daphnia* abundances in 2011-2013 suggest either an increase in food for *Daphnia* or reduced predation pressure in summer, or both, after installation of the aerators. Seasonal mean chlorophyll-a concentrations were similar in 1999-2001 vs. 2011-2013 (Figure 5; GEI 2014), but the seasonal mean *Daphnia* density was higher in the post-aerator period (mean=14.6 daphnids/L) versus in the pre-aerator period (mean=6.0 daphnids/L). Unfortunately, phytoplankton samples were analyzed by different labs with different methods between the two periods. Thus, changes in the proportion of edible algae after aerators were installed cannot be conclusively determined. That chlorophyll density was similar in 1999-2001 and 2011-2013 but *Daphnia* density seems to have been higher in the latter period tentatively suggest that grazing by zooplankton in recent years may not be able to keep up with algal production in the reservoir. Better information on the taxonomic composition of the phytoplankton is required to understand relationships among producers and grazers at CCR. Quantitative estimates of gizzard shad and other planktivore abundance would be needed to evaluate the predation (top-down) hypothesis for *Daphnia* density. That is, are *Daphnia* prevented from grazing down phytoplankton biomass because the *Daphnia* are limited by their predators (e.g., shad).

Top-down effects of predators on nutrient cycling and phytoplankton production have been demonstrated in a variety of north-temperate lakes (e.g., Kitchell et al. 1992; Carpenter and Kitchell 1993). Others have questioned the generality of top-down controls on water quality in reservoirs dominated by gizzard shad (Dettmers and Stein 1996), which may regulate food web dynamics through “middle-out” control (DeVries and Stein 1992). Because of high fecundity and rapid growth, gizzard shad can escape control by their predators (e.g., walleye), and their omnivorous feeding buffers them from effects of depleting their zooplankton prey. As stated above, quantitative estimates of gizzard shad abundance (and other important planktivores) are needed to better understand the relative importance of nutrients and food web effects on water quality at CCR.

The invasive tropical cladoceran *Daphnia lumholtzi* was found in CCR in 2011 and 2012 (but not in 2013). *Daphnia lumholtzi was* first detected in the United States in the early 1990s (Havel and Hebert 1993) and in Colorado at Pueblo Reservoir (Pueblo County) in 2008 (Benson et al. 2014). The species has since been found in Douglas Reservoir (Larimer County), Chatfield Reservoir (Douglas County), and John Martin Reservoir (Bent County) (Benson et al. 2014). Their abundance in temperate waters usually peaks in late summer when other cladocerans are typically rare, reducing the opportunity for competition (Lemke et al. 2003). *Daphnia lumholtzi* is resistant to predation by very small fish due to the presence of pronounced helmet and tail spines. However, their high thermal optimum (>26°C) and rarity during periods when age-0 fish are small suggests that their impact to the food web in CCR will be very limited.

Fish populations

Colorado Parks and Wildlife fish surveys were conducted with a variety of sampling gear types and were used in different months across years (Table 3). No surveys were conducted in 1983, 1990, 1999, 2000, 2002, 2003, 2005, 2007, 2009, or 2010. In some years the type of gear used was not listed or the catch from more than one type of gear was aggregated. Comments recorded for electrofishing surveys suggested that at least in some years not all species observed were captured. This made it difficult to compute catch per unit effort and interpret size structure differences among months and years. August and September were the most frequently surveyed months so in some cases analyses were restricted to these months.

Walleye growth and size structure

Based on modal lengths in September size distributions, it appeared that the maximum size of age-0 walleye in CCR in September was about 200 mm TL (mean = 161 mm, SD = 26 mm, n = 12). Allowing for incomplete growing seasons when CCR surveys were conducted, the first year growth of walleye was similar to the median (174 mm) reported for the species in FISHBASE (Froese and Pauly 2011). Mean size at age-0 also differed among years suggesting annual variation in growth conditions for young walleye (Figure 6). First summer growth of walleye did not appear to be related to the mean density of zooplankton during April-September. Of years when walleye and zooplankton data were available, age-0 walleye growth was similar in 2001, 2011-2013 yet 2011 had the highest zooplankton density and 2001 had the lowest zooplankton density. Walleye are known to transition to piscivory early in their first year of life (Mittelbach and Persson 1998). Thus, it is not unexpected that age-0 walleye growth is not correlated with zooplankton density. In Ohio reservoirs growth and survival of stocked hybrid walleyes were not related to zooplankton density. There, it appeared that if hybrid walleyes were stocked before larval gizzard shad appeared, the walleyes grew faster but survival to fall was lower than in years when walleye stocking occurred after larval shad appeared. They concluded that fisheries managers can adjust stocking date to increase first year growth or survival to fall but not both.

Sparse data prevented me from estimating length at older ages but histograms suggested that size at age-2 was also similar to that reported in FISHBASE (306 mm). These growth estimates are uncertain because of differential sampling gear bias across years. Otoliths or dorsal spines could be collected in the future to corroborate growth estimated from length-frequency analysis. Interannual differences in length distributions of walleye captured in August and September surveys were also somewhat difficult to interpret because the gear types used were not consistent. However, in most years it appears that at least five age-classes were sampled (Figure 7,8) suggesting regular recruitment. Walleye of ≥ quality size (≥ 380 mm) were nearly always sampled and in most years fish of preferred size (≥ 510 mm) and memorable (≥ 630 mm) sizes were also present. It appears that the present fishing regulation on walleye (18" minimum, daily bag limit of 3 and only 1 fish over 21") is effective in preventing overharvest of small to medium size walleye. While the number of trophy walleye (≥ 760 mm) sampled was low, overall, the size structure of the walleye population in CCR is probably highly desirable to anglers. There is no evidence from fall surveys that the size structure of the walleye population has declined since installation of the aerators.

Walleye body condition

Relatively high summer water temperature and periodic hypoxia at Cherry Creek Reservoir probably influence the growth and condition of the reservoir's walleye population. Specifically, walleye in Cherry Creek Reservoir may experience a "midsummer growth depression", unless very high food availability can compensate for increased metabolic costs. This temporary loss of weight during warmest times of the year has been documented in walleye populations outside Colorado, such as Lake Mendota, Wisconsin (Vogelsang et al. 1993) and Oneida Lake, New York (Forney 1977). The combination of suboptimal temperature and hypoxia may limit walleye growth, condition, and production in some years. Unfortunately, too few surveys were conducted in early summer (June-July) to compare condition to that measured later in summer (August-September). Regardless, annual growth increments are satisfactory, suggesting that possible energetic stress in summer is compensated by abundant food at other times of the year.

Fish population surveys in August and September suggest that body condition of walleye has changed little since 1986 (Figure 9). In general, relative weights of all sizes of walleye were close to 100, indicating a population in good body condition. It does not appear that walleye body condition has changed since the installation of the aerators. Continuing to monitor fall body condition of walleye would be prudent, in part because this index has been correlated with subsequent walleye recruitment in other systems (Madenjian et al. 1996; Zhao et al. 2013).

Walleye recruitment

An average of 2.47 million walleye fry were stocked into CCR each year, and about 17,000 fingerlings/yr were stocked in most years since 1998 (Table 4). The only year that no stocking of walleye occurred was 1984. Fish presumed to be age-0 were present in every August survey and in every year except 1996 when surveys were conducted in September, suggesting regular recruitment. This was despite variable *Daphnia* density during the critical larval period of planktivory, during May (Table 2). When rainbow smelt eliminated *Daphnia* in Horsetooth Reservoir, walleye recruitment failed (Johnson and Goettl 1999). Thus, survival of walleye stocked in CCR as fry might be lower in years with less *Daphnia* present, but lack of quantitative estimates of age-0 walleye abundance in CCR makes it impossible to evaluate this effect with existing data.

Presumed age-0 walleye were detected in fall 1984, when no stocking occurred. Other than that case, it is not possible to determine if natural reproduction is occurring from survey data because walleye fry and/or fingerlings were stocked in every other year. Analysis of strontium isotopes in walleye otoliths (Wolff et al. 2012, 2013) could be used to determine if walleye stocked as fingerlings show up in fall surveys. It is doubtful that fish stocked as fry could be distinguished from wild walleye using strontium analysis. Stocking only in alternate years could be used to determine if fry stocking is successful or fish are reproducing in the reservoir.

Biologists may be unwilling to discontinue annual stocking given that the walleye population has thrived under the status quo management. However, if the population is self-sustaining then walleye fry not stocked into CCR could be used to supply other waters.

Timing of walleye stocking

On average, the reservoir reached the typical spawning temperature for walleye on about April 5 (Figure 2). At these temperatures, naturally spawned walleye would be expected to hatch and begin exogenous feeding around May 5. In 2014, CPW collected ripe walleye eggs from the reservoir during March 19- April 2 (Ken Kehmeier, CPW, unpublished data), which is earlier than predicted by reservoir temperature. The average date that walleye fry were stocked at CCR during 1985-2013 was April 7, and fry are about three d old when stocked (Ken Kehmeier, CPW, pers. comm.). Stocking fry early in April may allow afford them little competition for zooplankton with other age-0 fish, but also means that young walleye must subsist without larval fish prey for longer than they would if they were stocked closer to the date when natural walleye fry and larval gizzard shad (May 26 or after) would be expected to be present. On average, walleye fingerlings were stocked on May 31, but stocking date ranged May 18- June 17. It is difficult to evaluate the successfulness of fingerling stocking since in nearly all years, fry were stocked in addition to fingerlings.

Gizzard shad

When years were lumped into 1995-2006 and 2008-2013 there was enough information to approximate size at age up to age-3 (Figure 10). These sizes at age are similar to those reported by Carlander (1969) in 10 states across the species' range (age-1: 130, age-2:224, age-3:284). The data suggest that GSD growth may have increased since the aerator was installed, but the post-aerator data are likely biased by incomplete sampling of GSD. Validation of estimated GSD ages with growth structures or another method is necessary before inferences about growth will become reliable. Relative weight of all sizes GSD was variable and generally below 100 (Figure 11). Since small fish were not included in the post-aeration samples, it is difficult to determine if body condition has changed but it the data suggest lower body condition in post-aerator years. This result contradicts the apparent increase in growth reported above.

It was not possible to evaluate gizzard shad recruitment from the CPW fish survey data because it appears that shad were not sampled in proportion to their abundance. For example, in 2006, 2008, 2011, and 2013 comments in the survey database stated "…thousands of YOY GSD observed…". In 2012: "thousands of 6-7" (150-180 mm) GSD observed, not collected." Only 2 fish < 290 mm appeared in the database in August/September surveys during 2006 and 2008, and only a small fraction of those observed were netted in later years. It is necessary to learn more about the CPW's specific sampling protocols before reliable conclusions about the status of the GSD population are possible.

Regardless of uncertainty in the data, it is clear that gizzard shad grow rapidly, and they probably become too large for most walleyes in CCR to consume them by the end of their second summer. This pattern is a typical shad predator-prey relationship between walleye and shad in many systems (e.g., Johnson et al. 1988; Ward et al. 2007). Since only young shad are vulnerable to walleye predation, consistent recruitment of gizzard shad is necessary for them to be a reliable prey base for walleye. Thus, in the future, tracking age-0 and age-1 gizzard shad growth and abundance could provide insights into the CCR walleye population's growth and condition. Quantitative estimates of GSD size and abundance are difficult to acquire due to their dense schooling and patchy distribution of schools (Johnson et al. 1988). However, a standardized subsampling procedure would be useful in future surveys to document the size distribution, age-growth and condition of shad in August/September. For example, surveyors could collect all GSD encountered in randomly chosen sections of shoreline. These data could then be used to compute catch per effort and an unbiased size distribution which would allow biologists to determine growth and year class strength of GSD in the future. Since year-class strength is often a function of overwinter survival of young of year shad, standardized catch-per-unit effort surveys of small gizzard in spring could be insightful into factors controlling shad abundance in CCR.

Gizzard shad have the potential to be a keystone species in CCR, with food web and water quality effects disproportionate to their abundance. They can control recruitment of the predators, like walleye, through competition for zooplankton with early life stages. They can deplete systems of the most effective grazers, like *Daphnia*, which can increase phytoplankton biomass, and they translocate sediment nutrients to the water column. All these characteristics suggest a species of particular importance to reservoir water quality.

CONCLUSIONS

- In general, over the period examined, the walleye population in CCR appears to have been quite strong. Growth was good, body condition was very good, medium and large size fish were always present, and recruitment was consistent. Apparently, fishery management practices have been effective in sustaining this population.

- As of 2013, there was no evidence that the installation of aerators has negatively impacted growth, condition, or size structure of the walleye population.

- It was not possible to evaluate the relative importance of stocking and wild recruitment in CCR walleye because stocking has occurred in almost every year of record. While the status quo management of the walleye population seems effective, if the population is self-sustaining then walleye fry not stocked into CCR could be used to supply other waters.

- Gizzard shad have the potential to be a keystone species in CCR. They are likely an important food source for walleye, but they also have the ability to limit walleye recruitment, and worsen water quality by depleting zooplankton grazers and recycling sediment nutrients. Understanding the effects of gizzard shad on the system requires regular (annual) monitoring of their abundance and size structure.

- The lack of zooplankton data immediately before and after installation of the aerators made inference about aerator effects on zooplankton difficult. More problematic is the uncertainty about taxonomic composition of the phytoplankton in the two periods.

- Total zooplankton density was similar across years, with the exception of 2011, when most taxa were more abundant than in other years. Total zooplankton density during April-September was not significantly different between pre- and post-aerator years.

- Impact to the CCR food web from the invasion of the tropical cladoceran *Daphnia lumholtzi* should be very limited. However, in the future, warmer reservoir conditions may allow the species to play a more prominent role.

- The density of *Daphnia* was variable across years but it was not possible to link changes in *Daphnia* to fish populations because fish abundance data were not available.

- During aerator years relatively high densities of *Daphnia* were observed in July and August. It is highly speculative, but the pattern of *Daphnia* abundances in 2011-2013 suggest an increase in food for *Daphnia* or reduced predation pressure in summer, or both, after installation of the aerators. However, it is not possible to test either hypothesis with the available data.

- The chlorophyll data tentatively suggest that grazing by zooplankton in recent years may not be able to keep up with algal production in the reservoir, despite some higher *Daphnia* densities. Again, this hypothesis is difficult to test with the present data.

- Quantitative estimates of gizzard shad and other planktivore abundance were not available but would be needed to evaluate the predation (top-down) hypothesis for *Daphnia* density.

RECOMMENDATIONS

Monitoring data on water quality and plankton at CCR are valuable for a better understanding of the interrelations of food web and bottom-up forces and their ultimate effects on water quality. Continued monitoring, consistent with historic methods, is recommended. These data will be particularly useful as more years with and without aeration accumulate. Further, these data will be useful for development and evaluation of the reservoir water quality model.

Effort should be made to determine how comparable the phytoplankton data are before and after the aerators were installed to evaluate potential direct effects of aeration on algae, and possible indirect effects on *Daphnia* biomass.

Continued monitoring of the fishery in September, using standardized methods and a statistically valid sampling design, is recommended. Standardizing sampling gear and protocols would make interannual comparisons more robust and insightful. Catch-per-unit effort of vulnerable size classes can be used as an index of recruitment. Accurate measurements of fish weight are required if fish condition indices are to be valid.

A limited amount of fish aging work is needed for validating inferences about fish age-growth presented here. Aging with otoliths is preferred for both walleye and shad, but dorsal spines can also be used in young walleye. Growth of both walleye and gizzard shad appears to be fast enough for the Petersen length-frequency method to be useful, but aging with chronometric body parts is needed to validate the method for use in the future.

Investigating the importance of stocking date and first year growth on survival of walleyes in CCR could provide useful insights to maximize the return on stocked walleyes. Little is known about the amount of natural reproduction or the relative effectiveness of fry and fingerling stocking of walleye here. Alternate year stocking, and Strontium isotope analysis of otoliths could determine if stocked fish contribute to walleye year class strength.

Given that gizzard shad are probably a keystone species at CCR, with implications for both water quality and the quality of the walleye fishery, a better understanding of gizzard shad population dynamics is needed. In addition to growth investigations recommended above, standardized electrofishing surveys of shad size and abundance in fall, coupled with spring surveys to evaluate overwinter survival are recommended.

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Table 1. Physical, chemical and biological habitat optima and preferences that comprise the Habitat Suitability Index (HSI) Model for walleye in lake and reservoir environments (McMahon et al. 1984).

Life stage	Habitat variable	HSI Optimum
Eggs	pH	6.0-8.5
	Oxygen (mg/L)	≥ 6
	Temperature (°C)	9-15
	Warming	≥0.28°/day
	Substrate	Rubble, gravel
	Water level	Stable or rising
	Flow (cm/s)	>0
Juveniles, adults	Trophic status	Mesotrophic
	pH	6.0-8.5
	Oxygen (mg/L)	≥ 4
	Temperature (°C)	22-24
	Cover	25-45%
	Secchi depth (m)	1-3
	Prey fish (mg/m^3)	≥ 400
	Flow (cm/s)	Low

Table 2. Mean April-May density (n/L) of four zooplankton groups in Cherry Creek Reservoir before (1999-2001) and after (2011-2013) aerators were installed.

Year	*Bosmina* spp.	Calanoid copepods	Cyclopoid copepods	*Daphnia* spp.	*Total zooplankton*
1999	105.6	1.8	23.1	7.6	138.2
2000	131.4	0.8	37.6	2.3	172.0
2001	23.9	1.6	16.7	1.8	44.0
Mean	87.0	1.4	25.8	3.9	118.1
2011	376.4	1.9	14.1	41.6	434.0
2012	26.6	1.3	21.2	1.9	51.0
2013	54.8	23.1	10.2	3.9	92.0
Mean	152.6	8.8	15.2	15.8	192.3

Table 3. Sampling gear used in fish surveys conducted by CPW during 1981-2013 at Cherry Creek Reservoir. Gear codes: EF=electrofishing, GN=gill net; MX=mix, NL=not listed, TN=trap net. No surveys were conducted in 1983, 1990, 1999, 2000, 2002, 2003, 2005, 2007, 2009, 2010.

Year	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT
1981				EF				EF
1982			EF					GN
1984						EF		
1985			NL	MX				
1986				EF			MX	
1987						EF		EF
1988							GN	
1989				GN				
1991		GN		MX		EF	TN	TN
1992			TN				TN	TN
1993			TN				TN	
1994				TN			MX	
1995	GN					EF		
1996			GN				EF	
1997					EF		EF	
1998							EF	
2001							NL	
2004							GN	
2006						MX		
2008							MX	
2011							MX	
2012						MX		
2013							MX	

Table 4. Walleye fry and fingerlings stocked into Cherry Creek Reservoir since 1985 (Colorado Division of Parks and Wildlife).

Year	Fry	Mean date	Fingerlings	Mean date
1985	2,346,000	1-Apr	0	.
1986	1,734,000	1-Apr	0	.
1987	1,760,000	10-Apr	0	.
1988	1,760,000	10-Apr	0	.
1989	1,352,000	10-Apr	0	.
1990	1,400,000	12-Apr	0	.
1991	1,300,000	8-Apr	0	.
1992	2,600,000	11-Apr	0	.
1993	2,600,000	7-Apr	0	.
1994	2,600,000	8-Apr	0	.
1995	2,600,000	6-Apr	0	.
1996	3,202,940	6-Apr	0	.
1997	2,600,000	2-Apr	0	.
1998	0	.	40,000	17-Jun
1999	1,971,060	16-Apr	0	.
2000	2,399,800	6-Apr	0	.
2001	2,444,520	5-Apr	0	.
2002	2,519,660	12-Apr	0	.
2003	4,136,709	14-Apr	0	.
2004	2,861,711	6-Apr	12,389	25-May
2005	2,548,939	1-Apr	31,000	31-May
2006	2,780,826	5-Apr	7,999	1-Jun
2007	4,300,000	10-Apr	7,998	23-May
2008	3,992,572	14-Apr	0	.
2009	4,012,800	7-Apr	14,998	4-Jun
2010	250,000	14-Apr	14,412	18-May
2011	4,001,400	5-Apr	0	.
2012	4,001,400	6-Apr	15,000	31-May
2013	4,000,360	3-Apr	7,822	12-Jun
mean	2,554,369	7-Apr	16,846	31-May
min	0	1-Apr	0	18-May
max	4,300,000	16-Apr	40,000	17-Jun

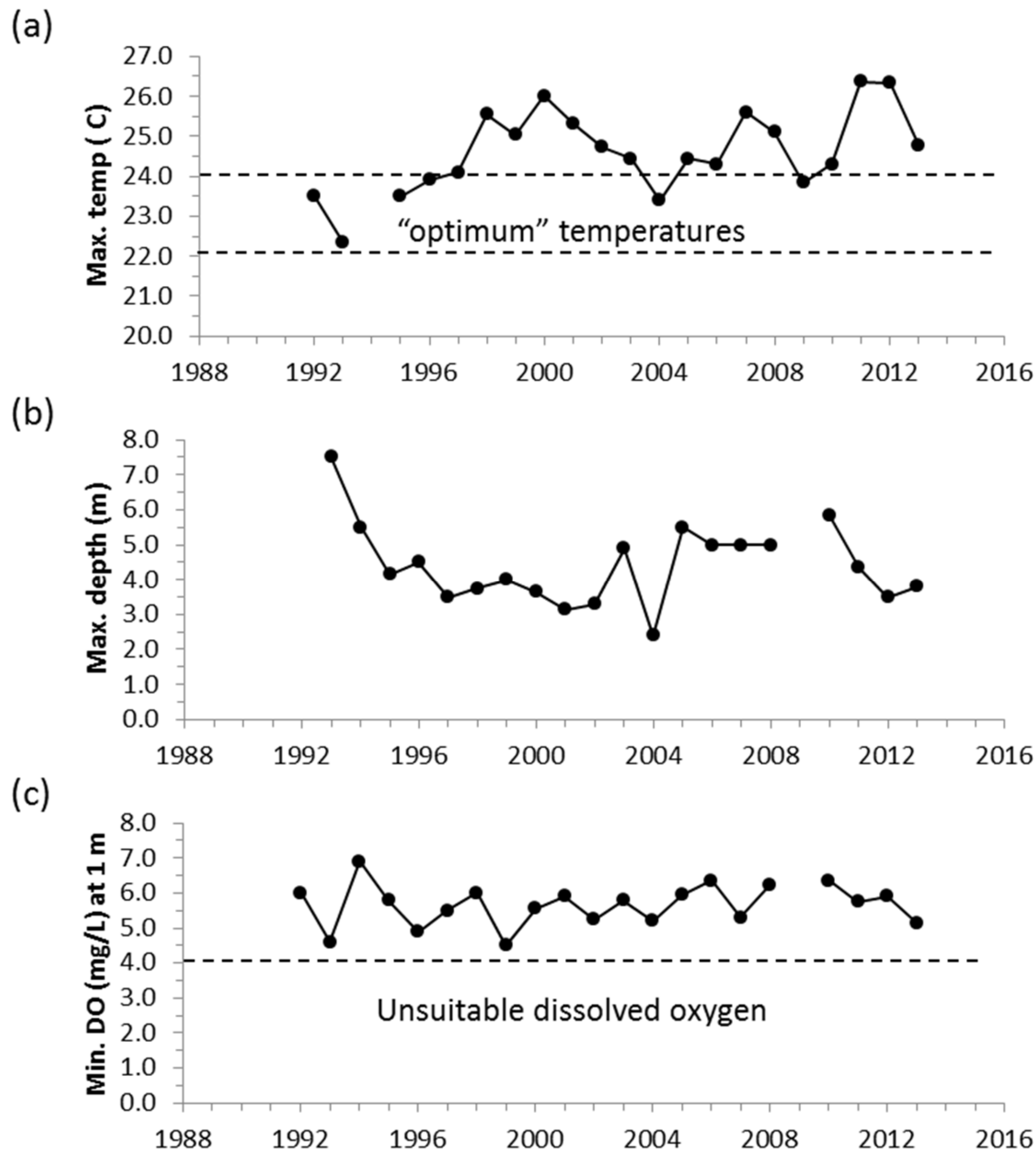


Figure 1.A. Maximum temperature measured at three sites on Cherry Creek Reservoir during 1992-2013. Optimum temperature for walleye is 22-24°C. B. Maximum depth at which ≥4.0 mg/L of oxygen was available in Cherry Creek Reservoir. C. Minimum recorded dissolved oxygen measured at 1 m depth in Cherry Creek Reservoir. (Note: 2009 DO data not considered reliable)

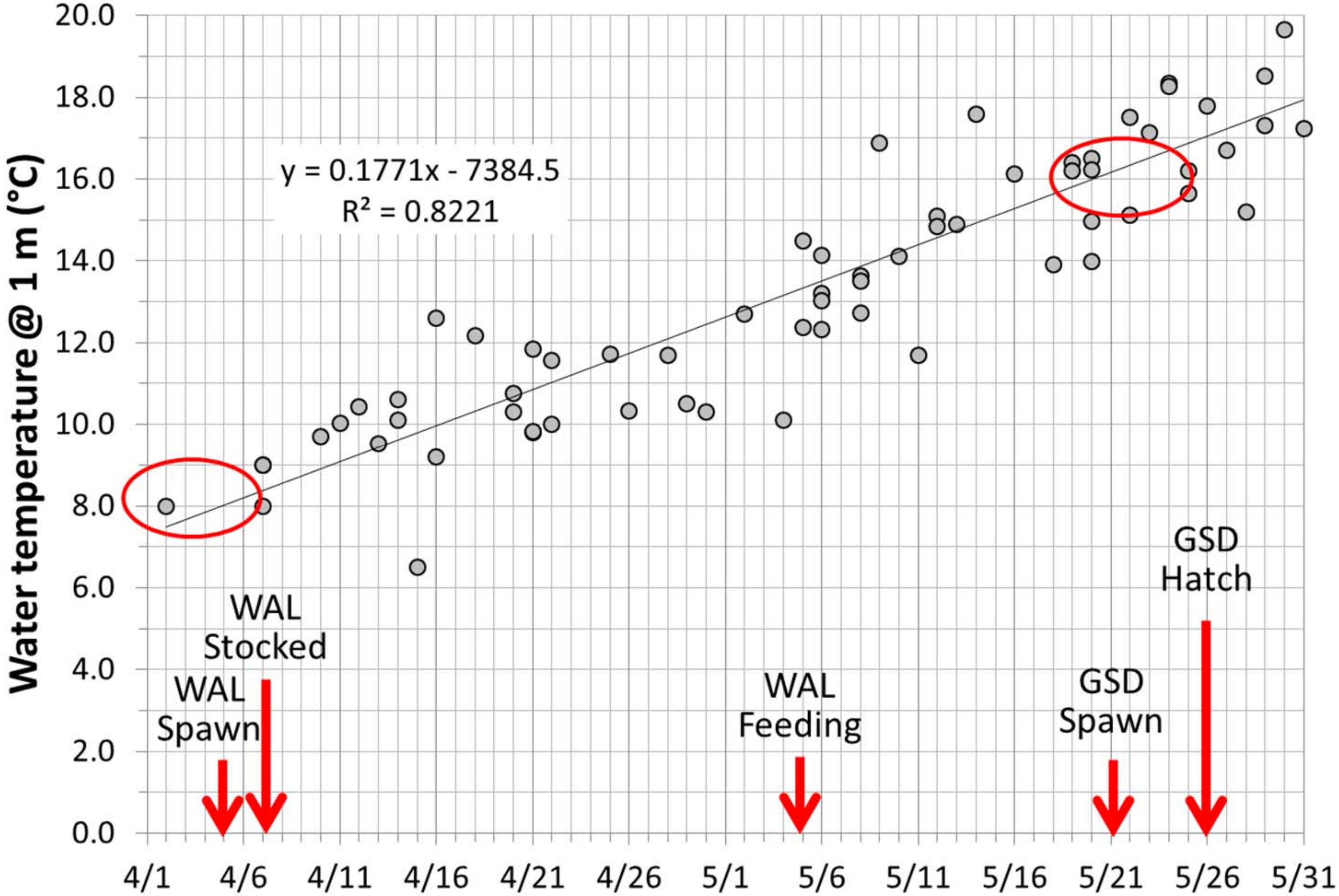


Figure 2. Surface water temperature at CCR during 1996-2012, with linear regression fit. Regression parameters are based on Excel date format, where the date value is represented as the number of days since 01/01/1900. Arrows indicate timing of stocking and early life history of walleye and shad in Cherry Creek Reservoir.

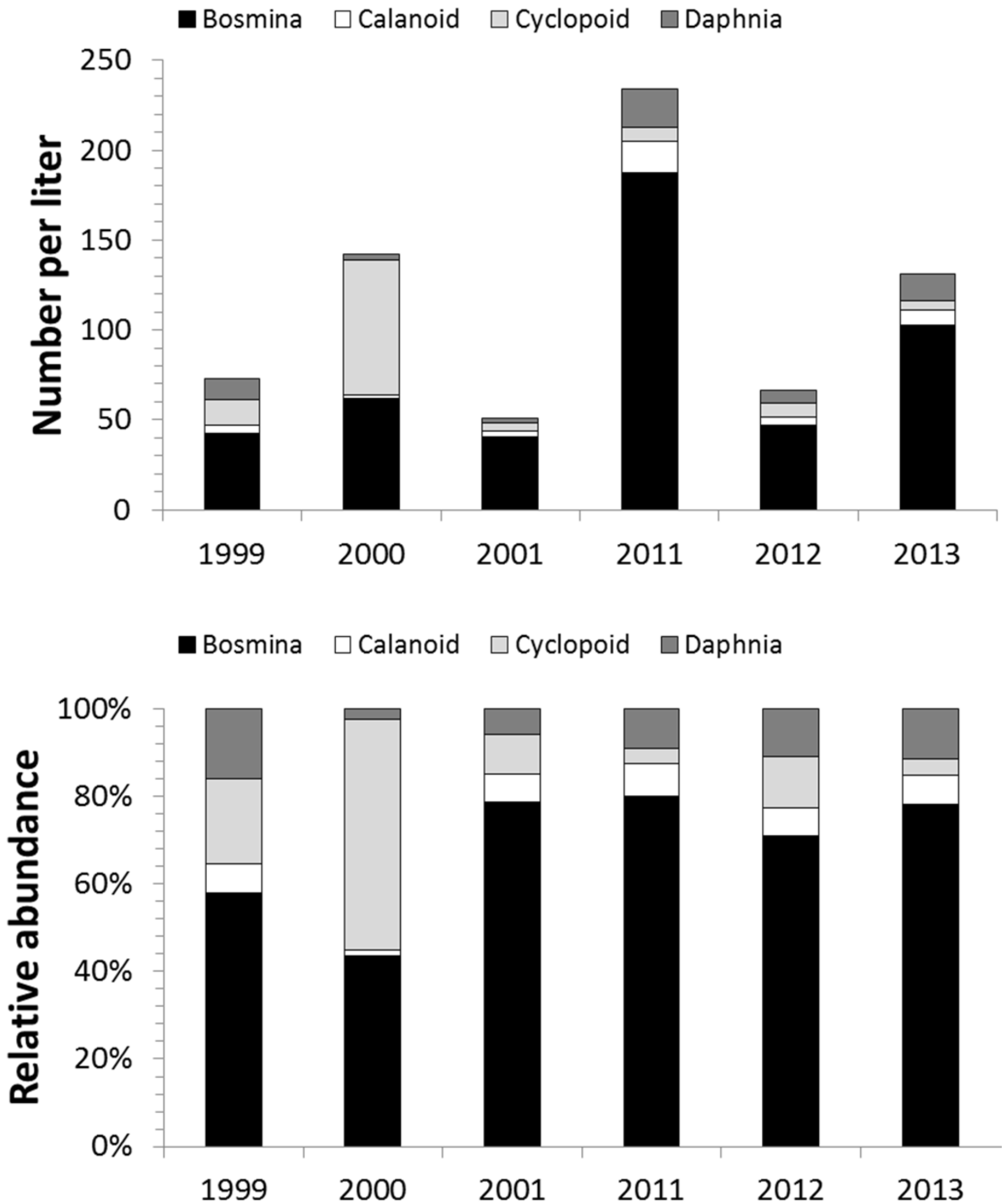


Figure 3. Annual mean abundance of four major taxa of zooplankton at Cherry Creek Reservoir (April-September only).

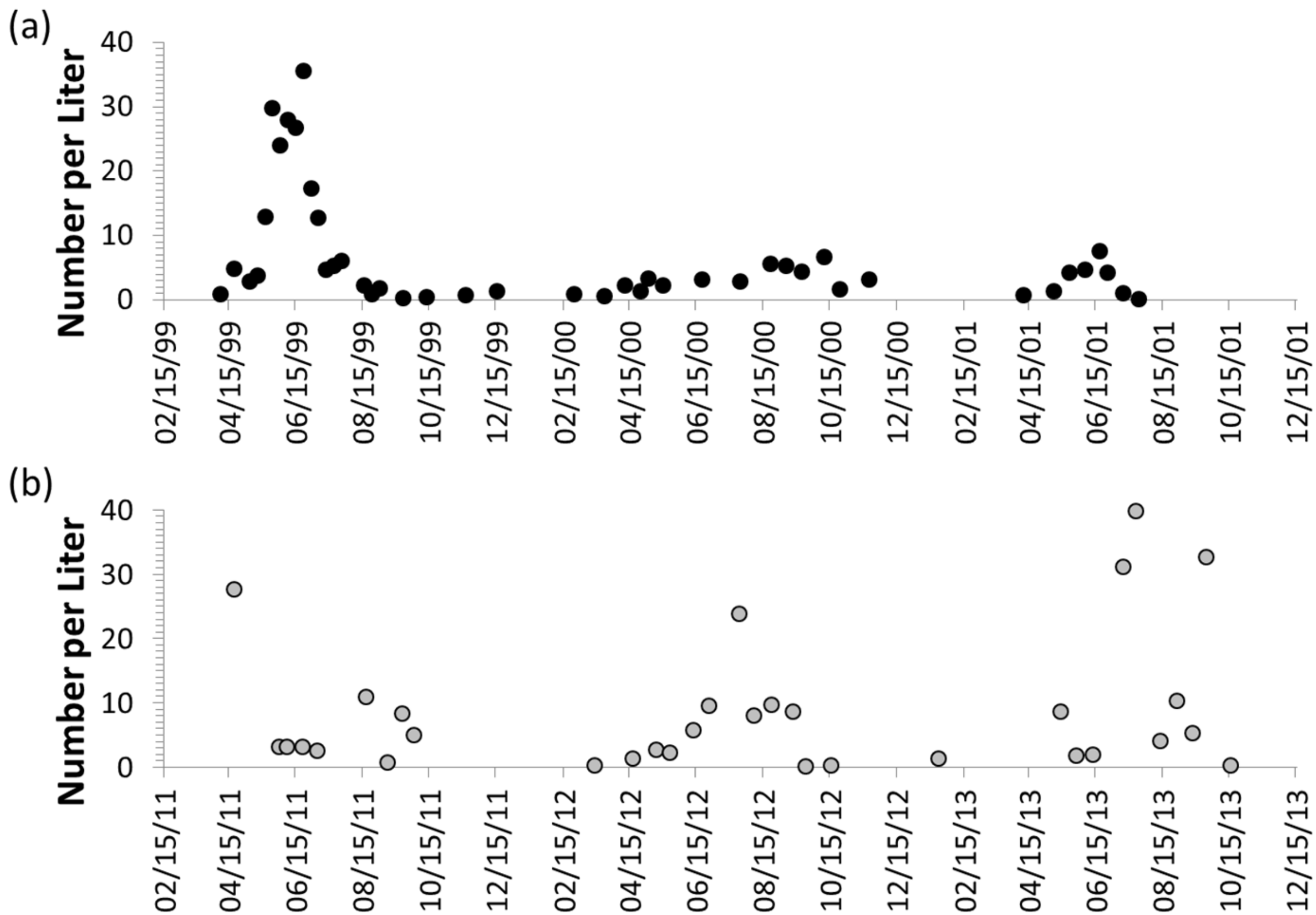
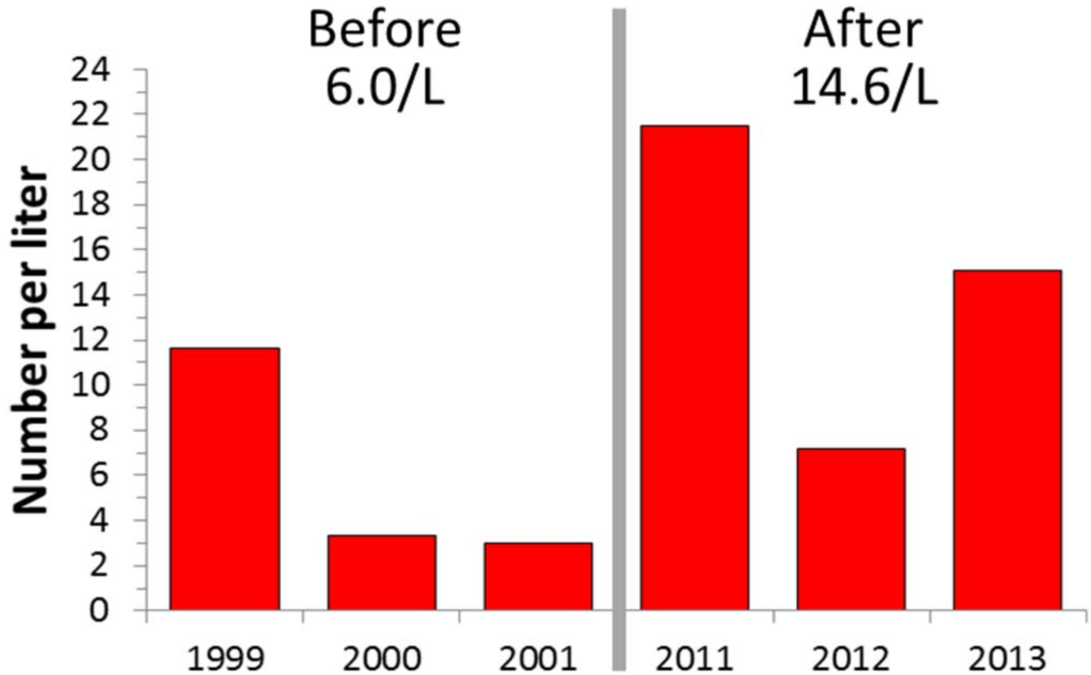


Figure 4. Density of *Daphnia* spp. (excluding *D. lumholtzi*) sampled at Cherry Creek Reservoir before (a) and after (b) aerators were installed.



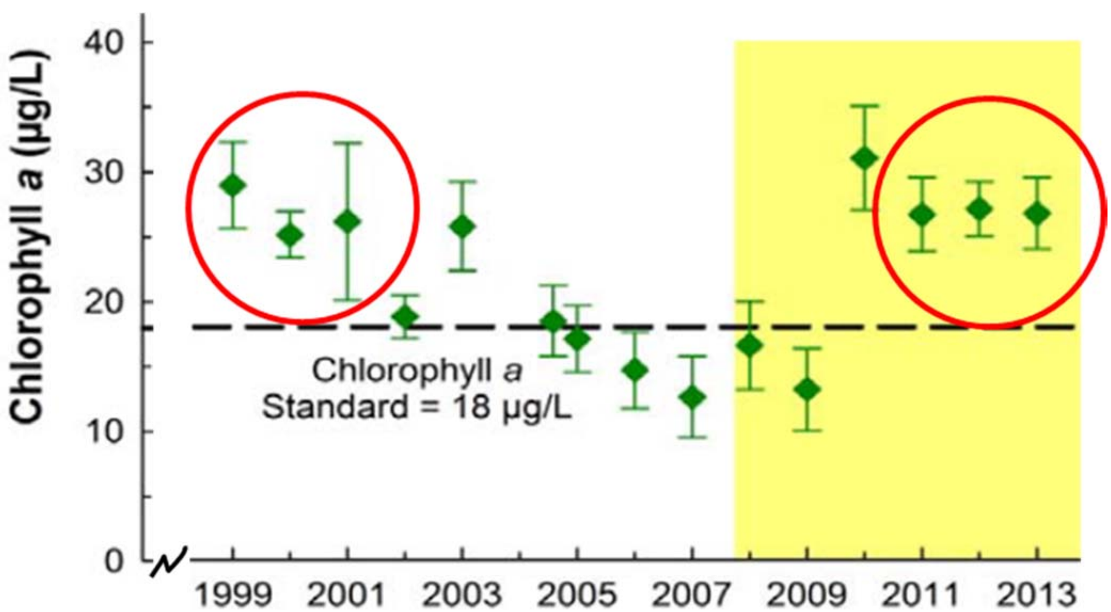


Figure 5. Mean seasonal Daphnia density in three years before aerators and three years after (top panel). Mean annual chlorophyll concentrations (lower panel) during these same periods are circled.

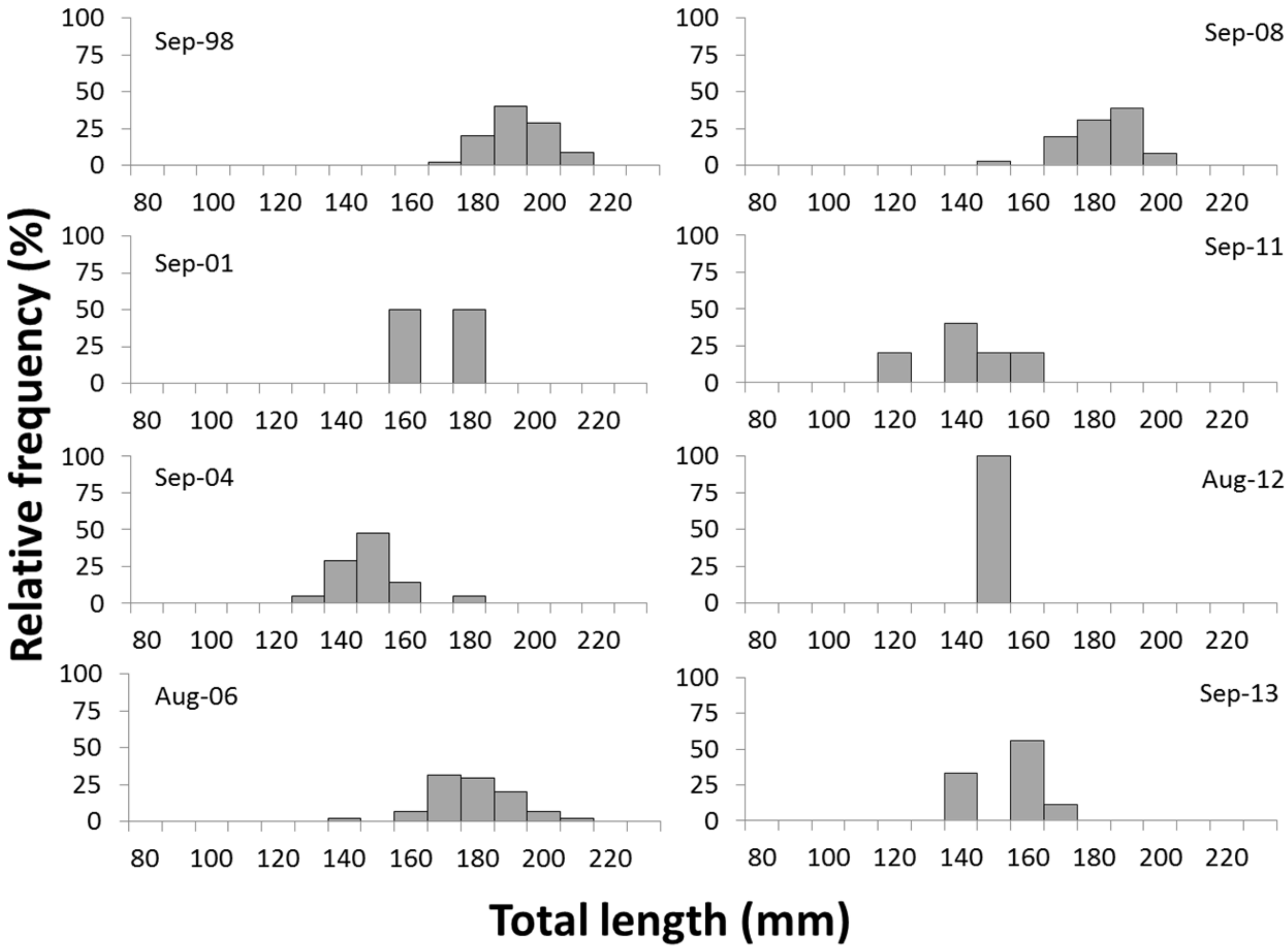


Figure 6. Length-frequency histograms of presumed age-0 walleye sampled in four years before (1998-2006) and four years after (2008-2013) the aeration system was installed at CCR

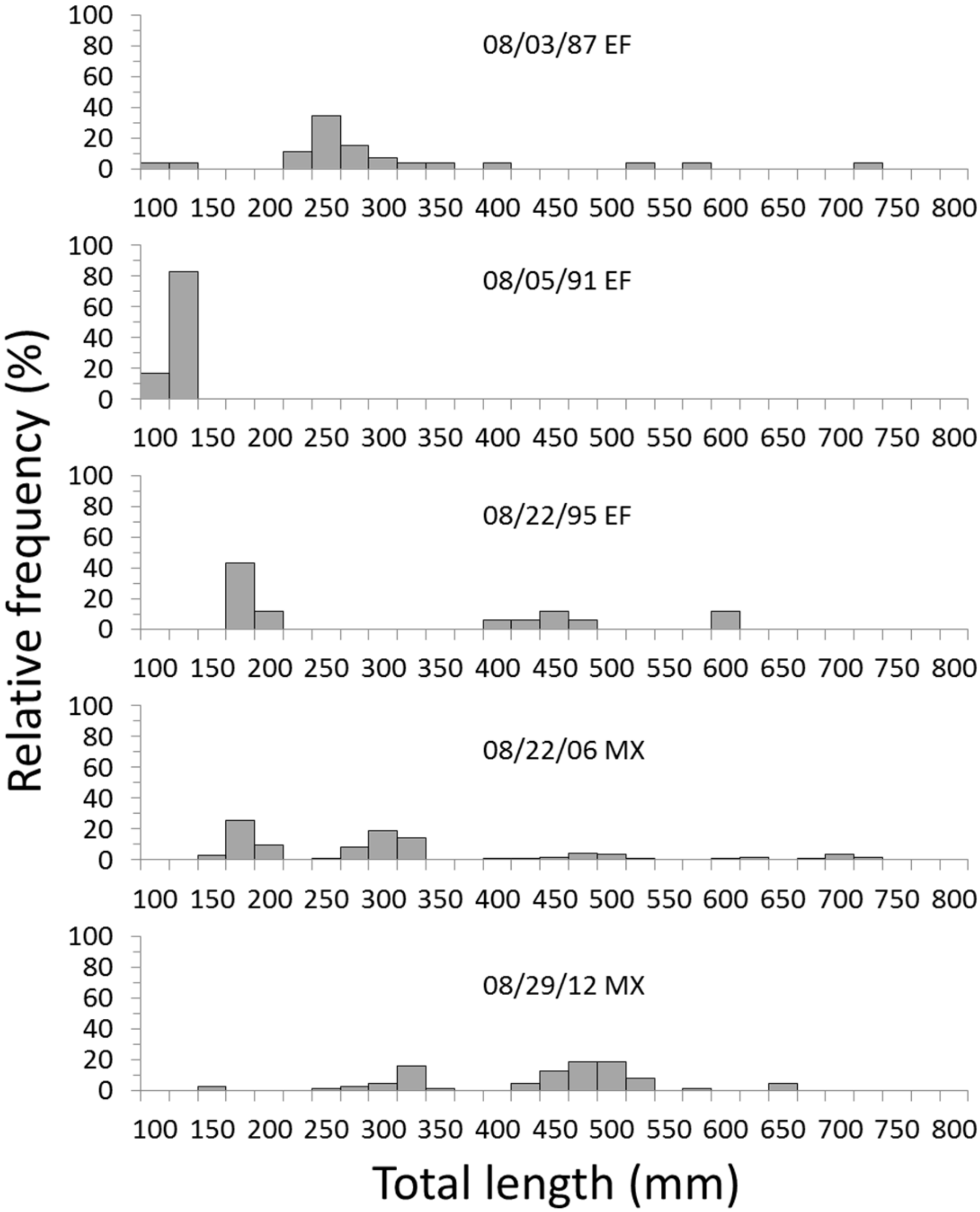


Figure 7. Length-frequency histograms of walleye sampled in August of years shown. Sampling method was electrofishing (EF) in 1984-1995, and a mix of gear types (MX) in 2006 and 2012.

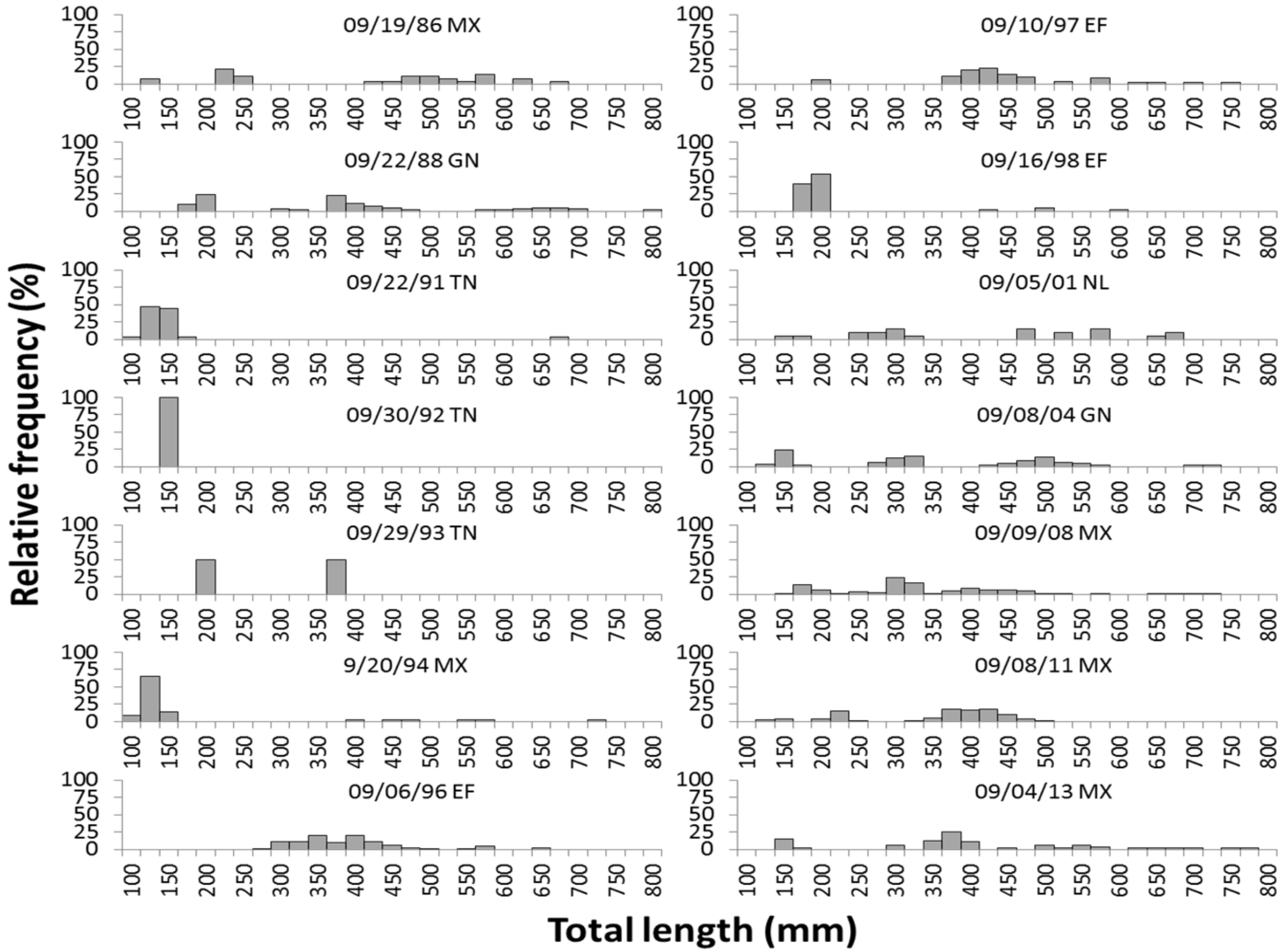


Figure 8. Length-frequency histograms of walleye sampled in September at CCR. Sampling method, listed with year: EF=electrofishing, GN=gill net; MX=mix, NL=not listed, TN=trap net.

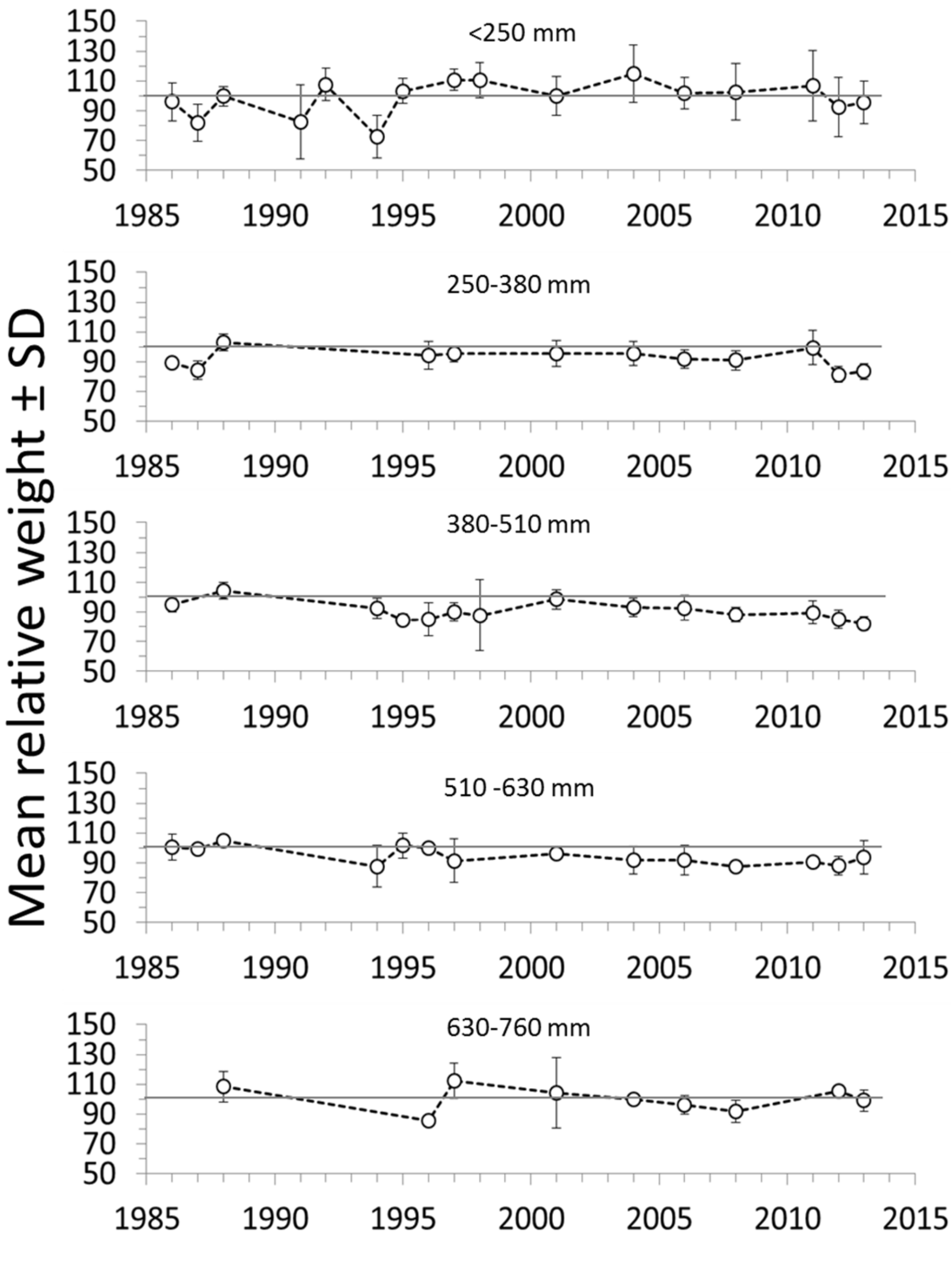


Figure 9. Relative weight of five size classes of walleye sampled at Cherry Creek Reservoir during surveys conducted only during August and September by CPW in 1987-2013.

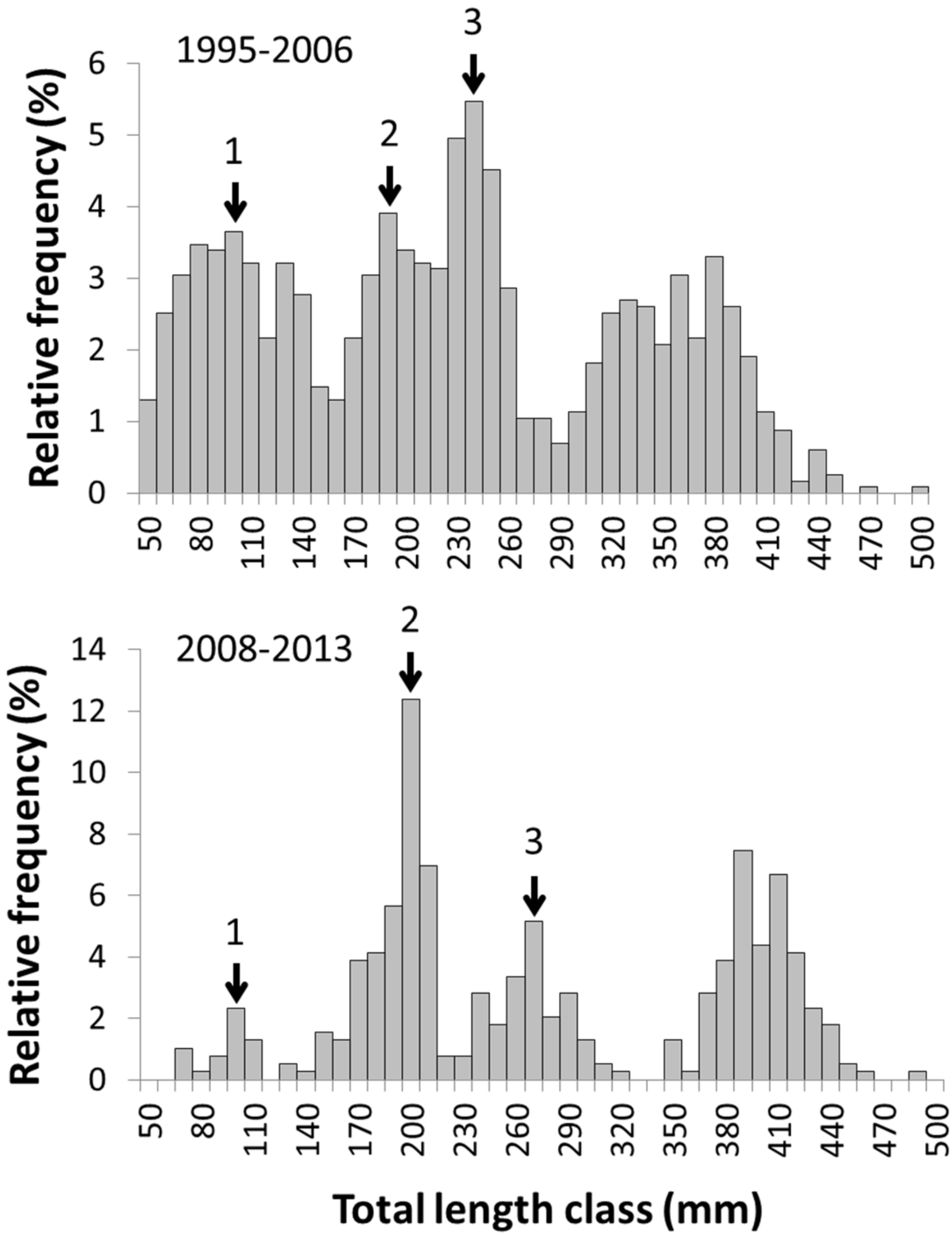


Figure 10. Length-frequency histograms of all gizzard shad sampled in August-September surveys of pre- and post-aerator years with data. Numbers represent estimated age (assuming growth is complete so age-0 fish are classified as age-1, etc.) and arrows represent approximate mean size at age.

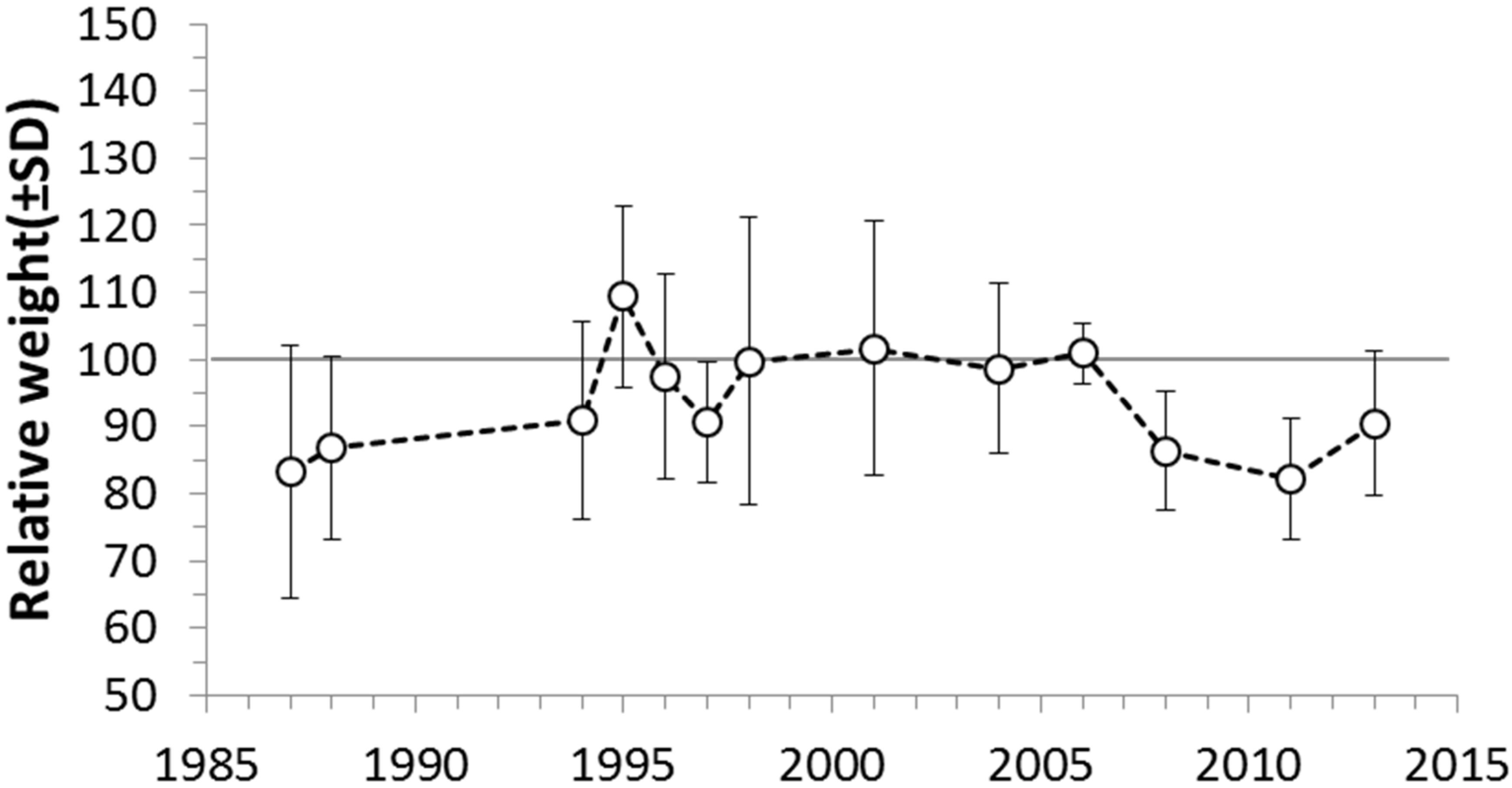
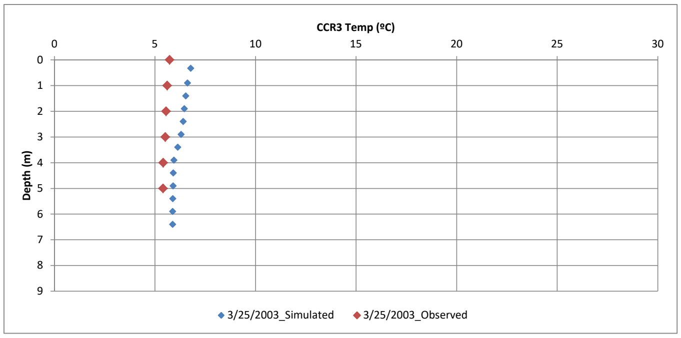


Figure 11. Relative weight of all size classes of gizzard shad sampled at Cherry Creek Reservoir during surveys conducted only during August and September by CPW in 1987-2013.

Attachment B: Temperature Calibration: Observed and Simulated Results

Contents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Depth (m)
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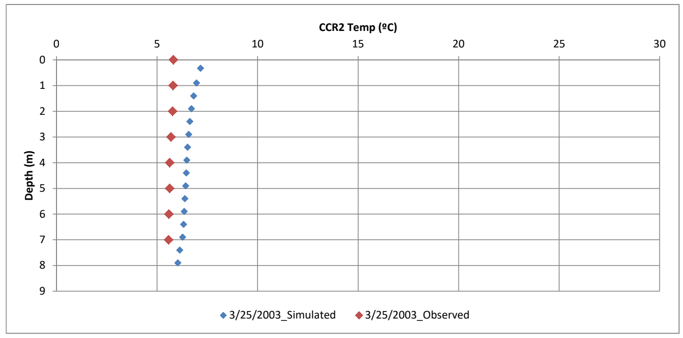
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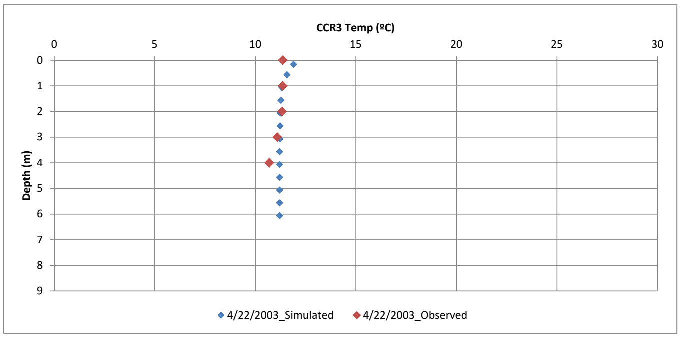
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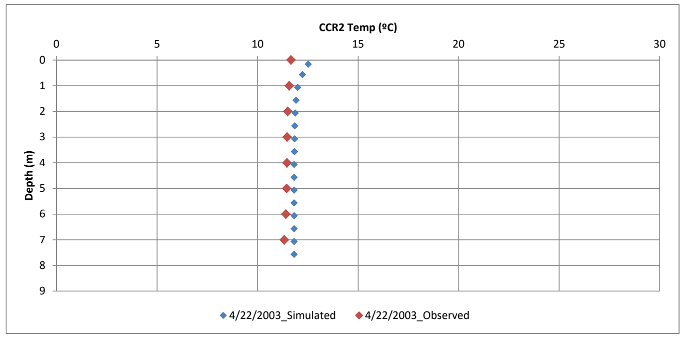
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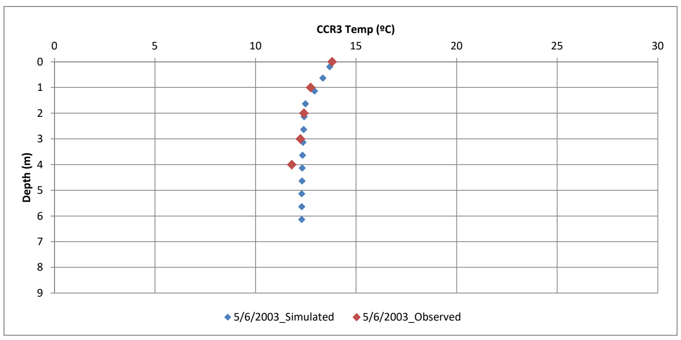
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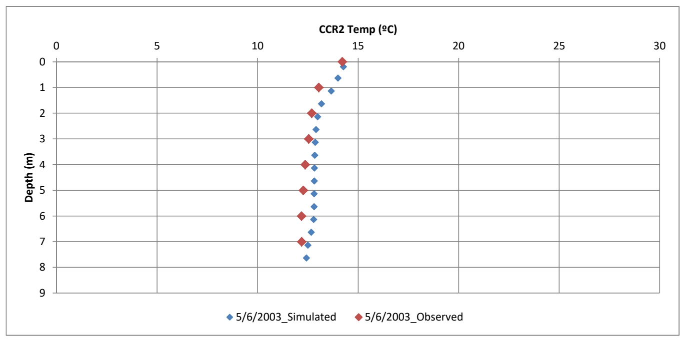
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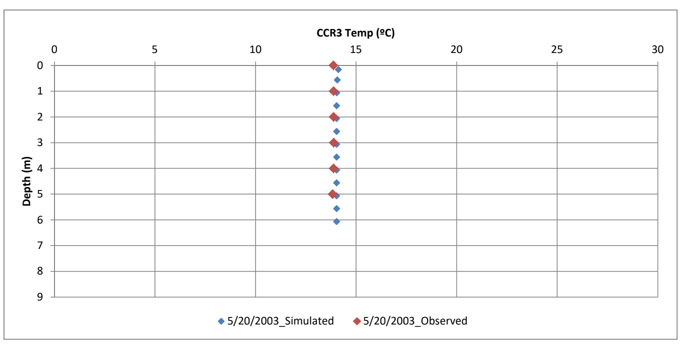
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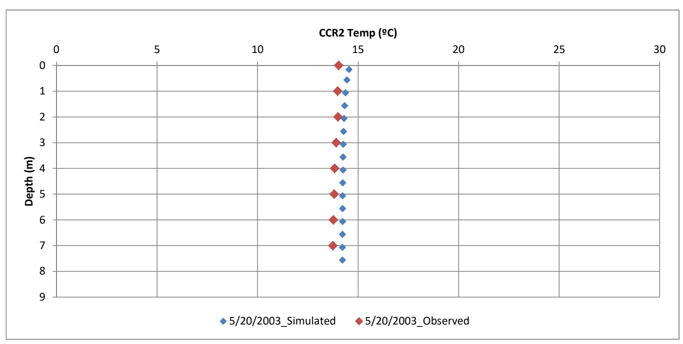
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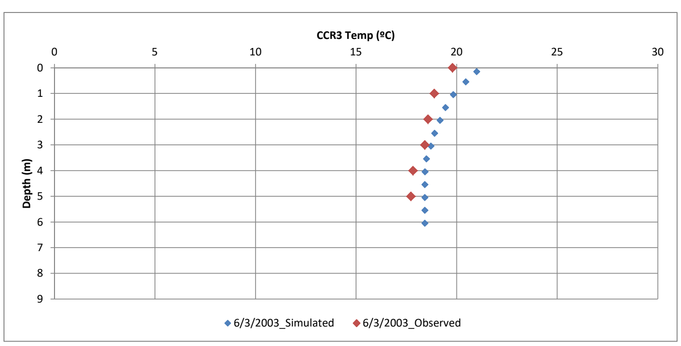
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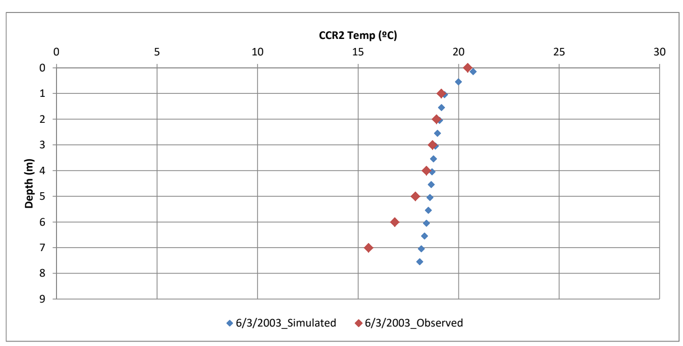
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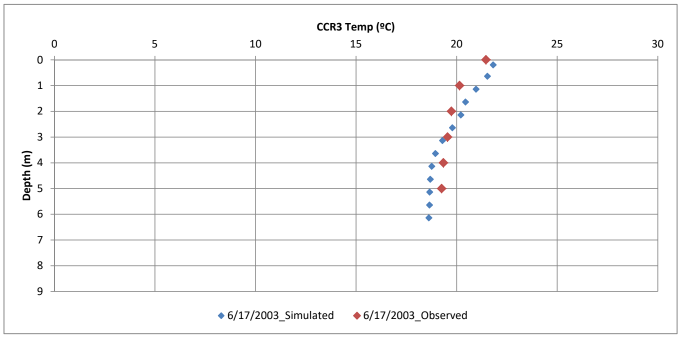
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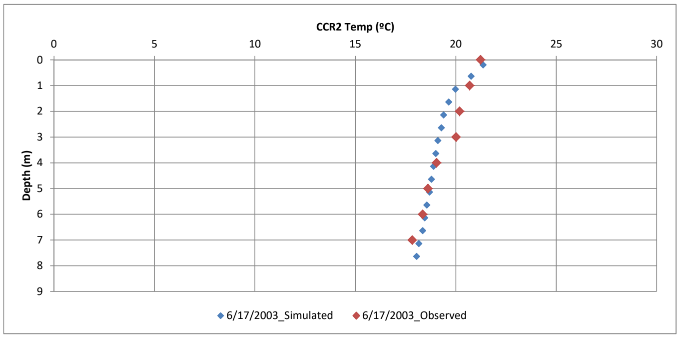
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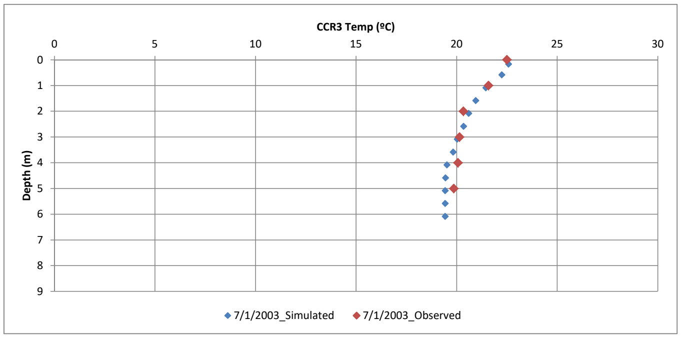
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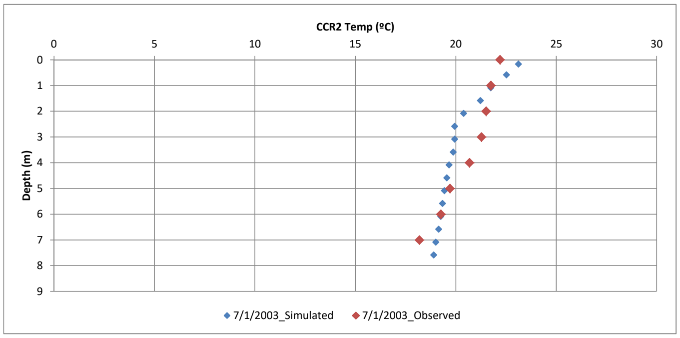
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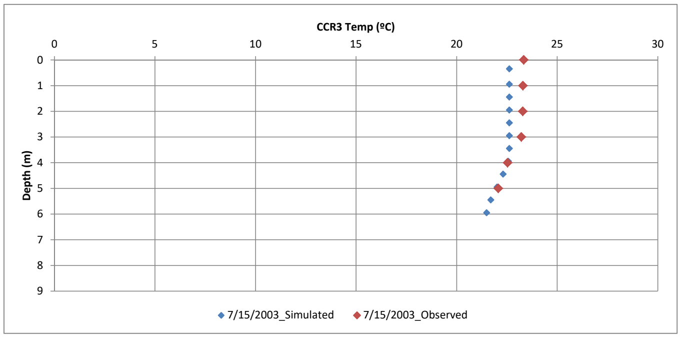
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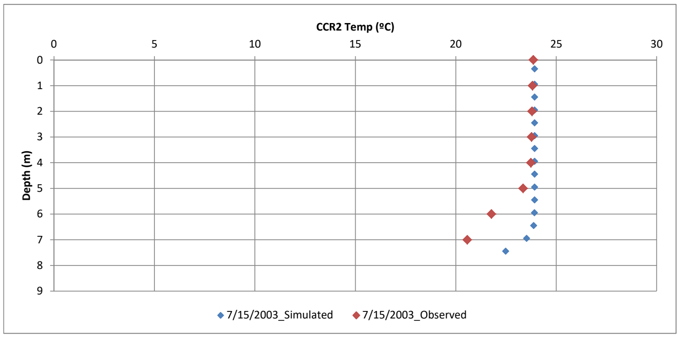
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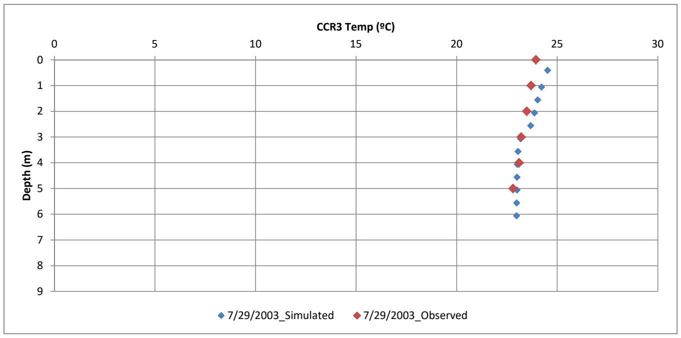
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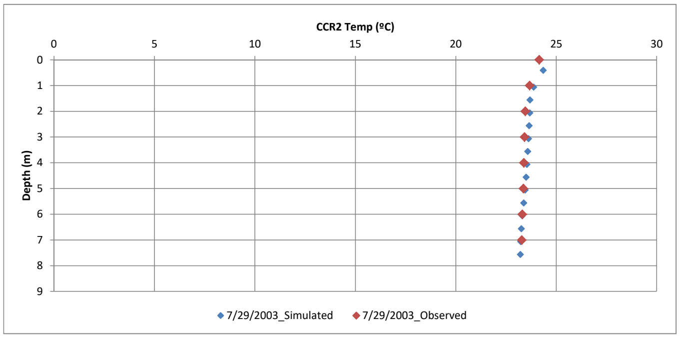
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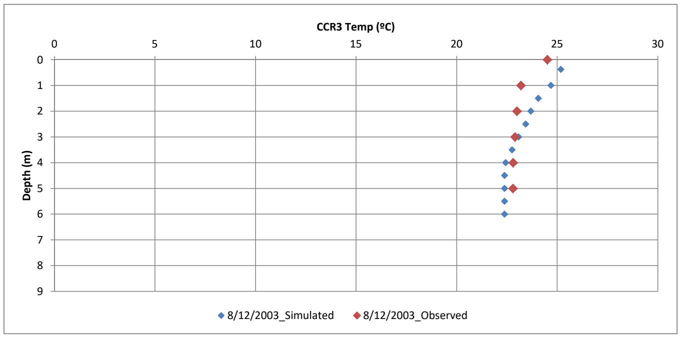
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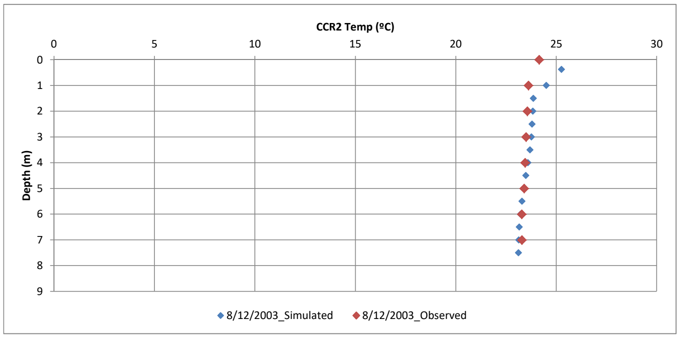
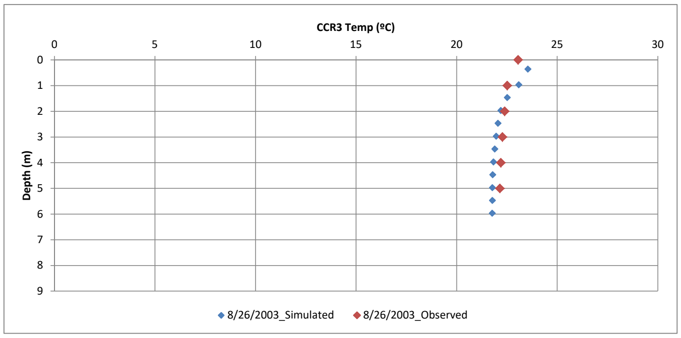
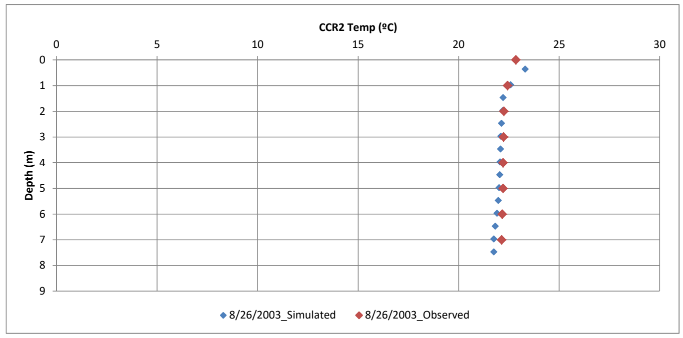
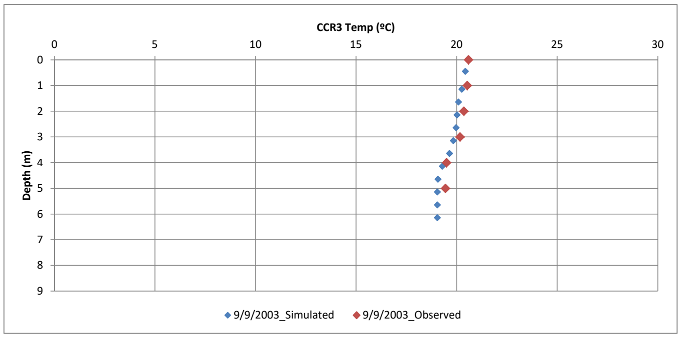
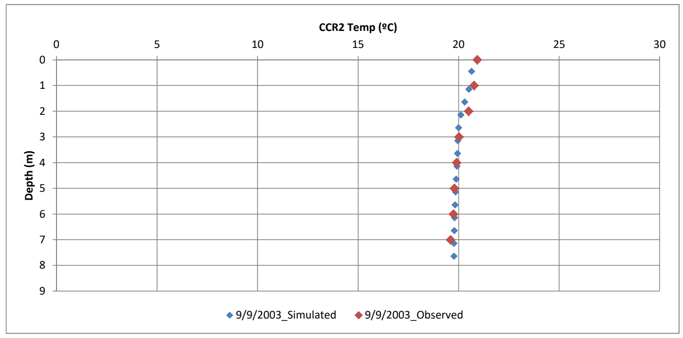
8/12/2003_Simulated
8/12/2003_Observed

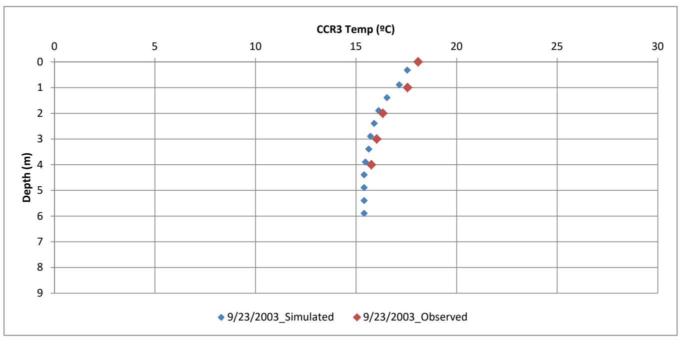

CCR2 Temp (ºC)
Depth (m)
8/12/2003_Simulated
8/12/2003_Observed

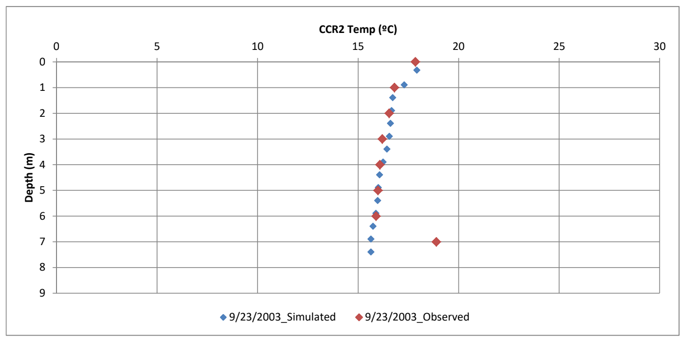

CCR3 Temp (ºC)
Depth (m)
8/26/2003_Simulated
8/26/2003_Observed

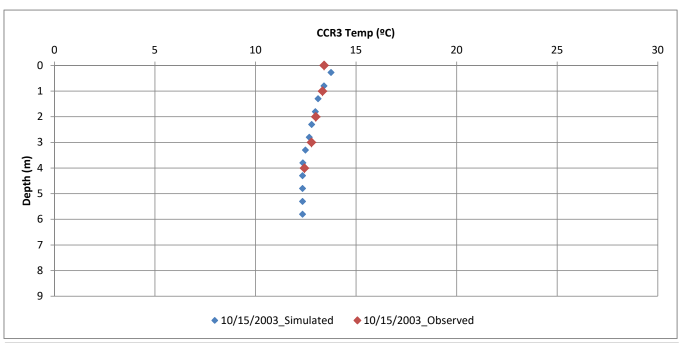

CCR2 Temp (ºC)
Depth (m)
8/26/2003_Simulated
8/26/2003_Observed

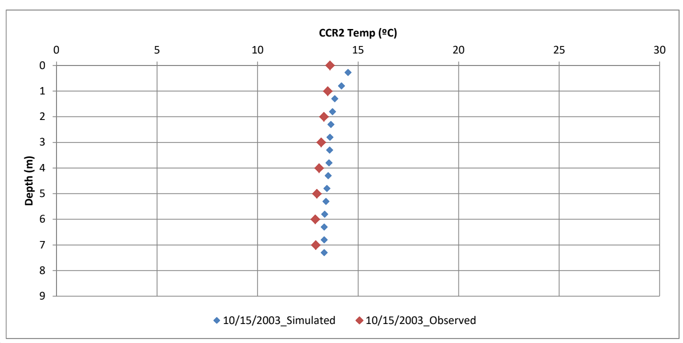

CCR3 Temp (ºC)
Depth (m)
9/9/2003_Simulated
9/9/2003_Observed

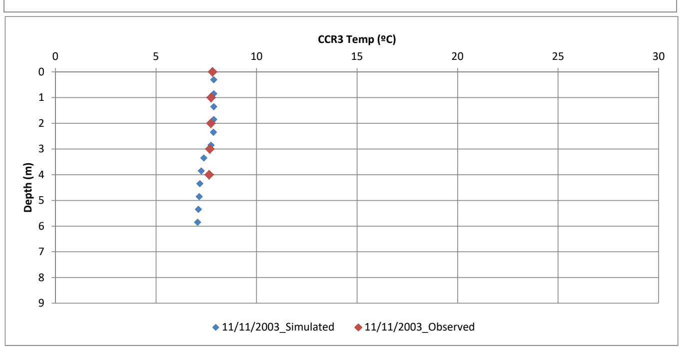

CCR2 Temp (ºC)
Depth (m)
9/9/2003_Simulated
9/9/2003_Observed

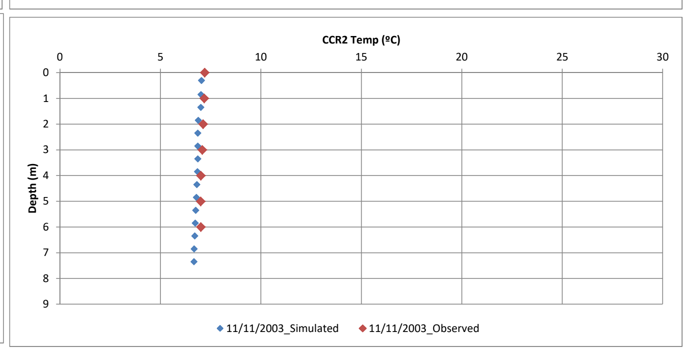

CCR3 Temp (ºC)
Depth (m)
9/23/2003_Simulated
9/23/2003_Observed

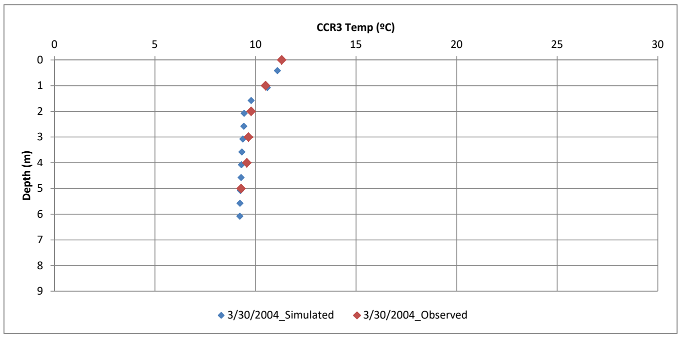

CCR2 Temp (ºC)
Depth (m)
9/23/2003_Simulated
9/23/2003_Observed

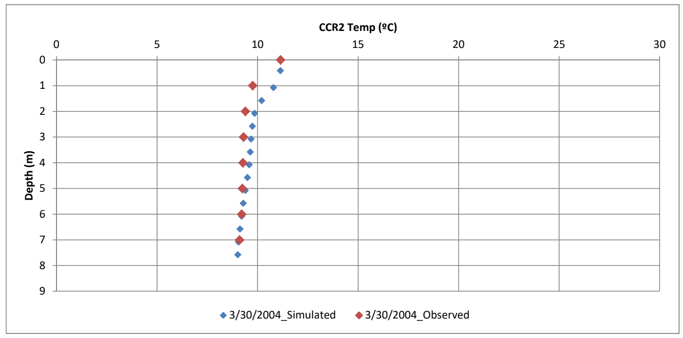

CCR3 Temp (ºC)
Depth (m)
10/15/2003_Simulated
10/15/2003_Observed

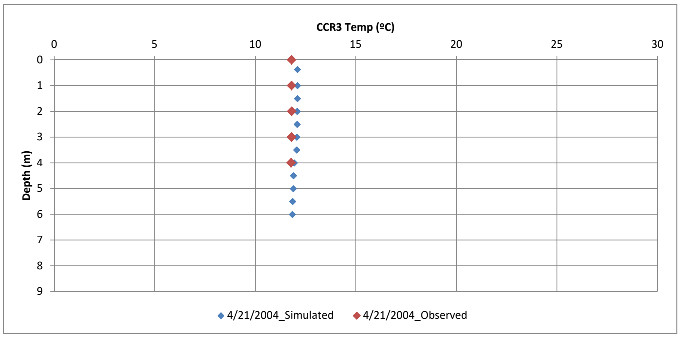

CCR2 Temp (ºC)
Depth (m)
10/15/2003_Simulated
10/15/2003_Observed

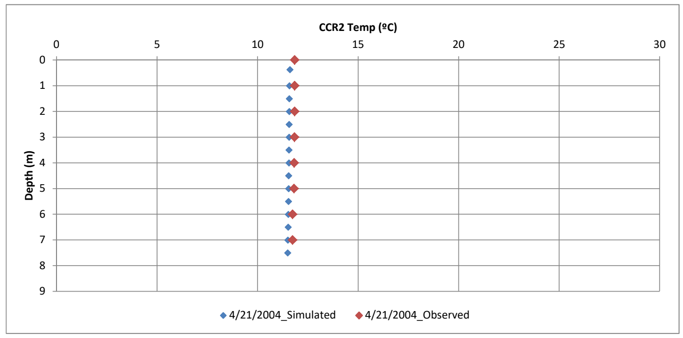

CCR3 Temp (ºC)
Depth (m)
11/11/2003_Simulated
11/11/2003_Observed

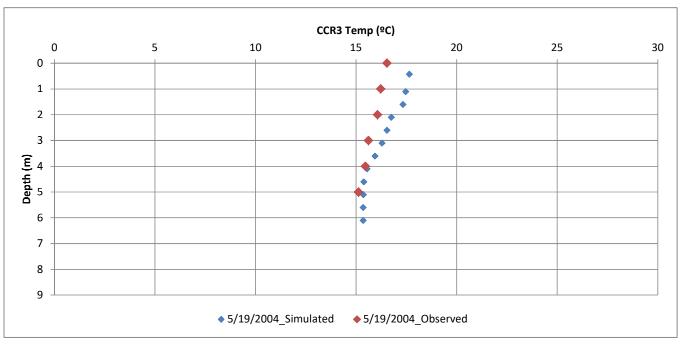

CCR2 Temp (ºC)
Depth (m)
11/11/2003_Simulated
11/11/2003_Observed

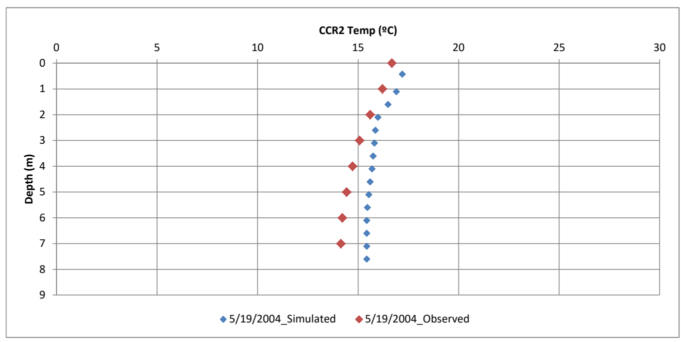

CCR3 Temp (ºC)
0 5 10 15 20 25 30
0 1 2 3 4 5 6 7 8 9
Depth (m)
3/30/2004_Simulated
3/30/2004_Observed

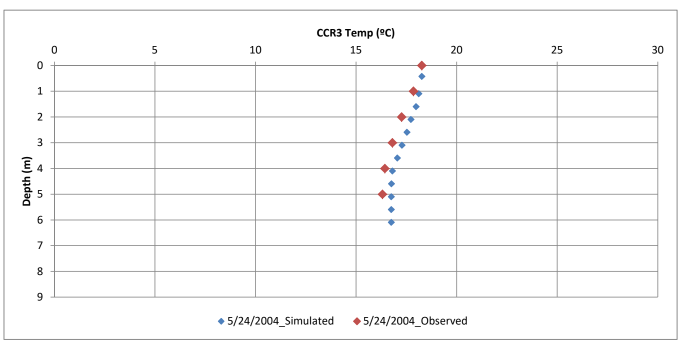

CCR2 Temp (ºC)
0 5 10 15 20 25 30
0 1 2 3 4 5 6 7 8 9
Depth (m)
3/30/2004_Simulated
3/30/2004_Observed

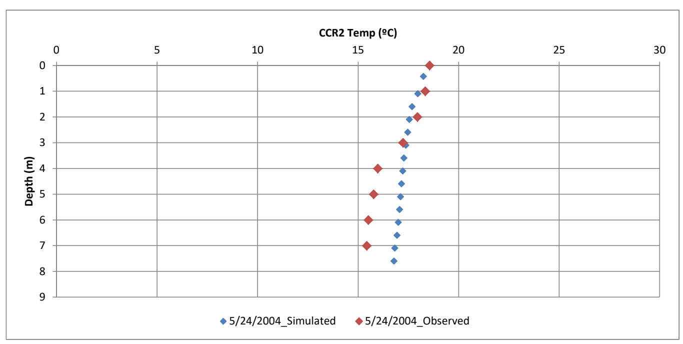

CCR3 Temp (ºC)
0 5 10 15 20 25 30
0 1 2 3 4 5 6 7 8 9
Depth (m)
4/21/2004_Simulated
4/21/2004_Observed

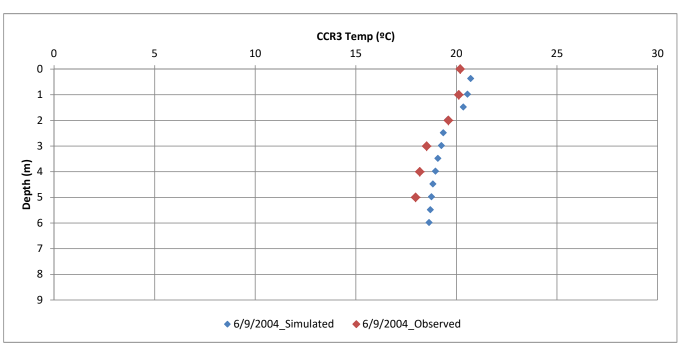

CCR2 Temp (ºC)
0 5 10 15 20 25 30
0 1 2 3 4 5 6 7 8 9
Depth (m)
4/21/2004_Simulated
4/21/2004_Observed

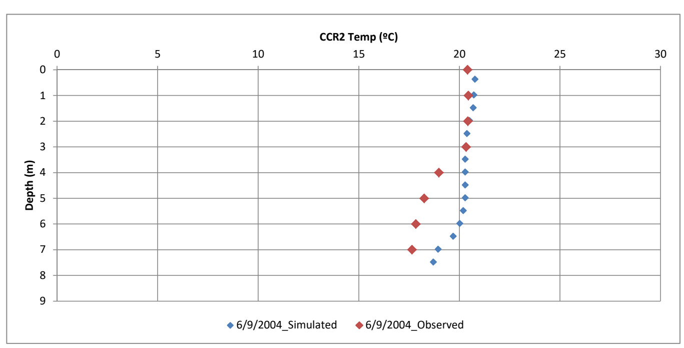

CCR3 Temp (ºC)
0 5 10 15 20 25 30
0 1 2 3 4 5 6 7 8 9
Depth (m)
5/19/2004_Simulated
5/19/2004_Observed

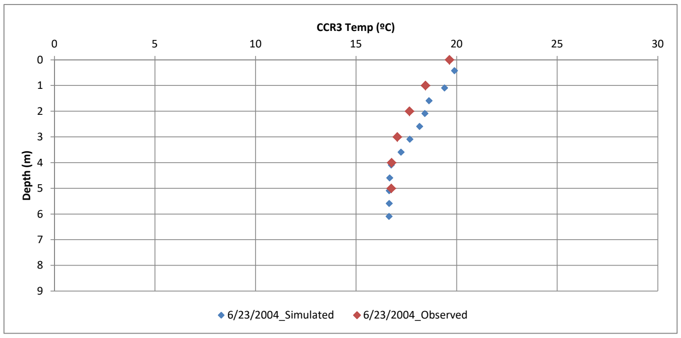

CCR2 Temp (ºC)
0 5 10 15 20 25 30
0 1 2 3 4 5 6 7 8 9
Depth (m)
5/19/2004_Simulated
5/19/2004_Observed

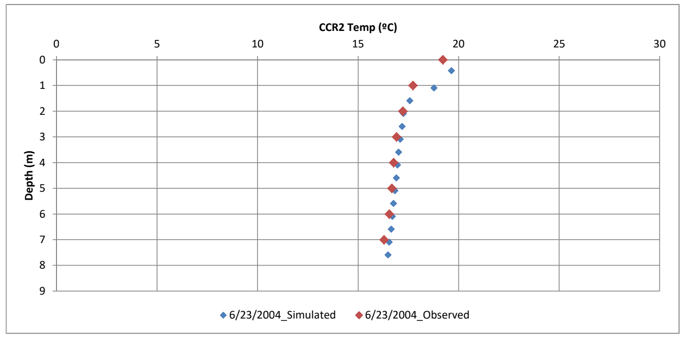

CCR3 Temp (ºC)
0 5 10 15 20 25 30
0 1 2 3 4 5 6 7 8 9
Depth (m)
5/24/2004_Simulated
5/24/2004_Observed

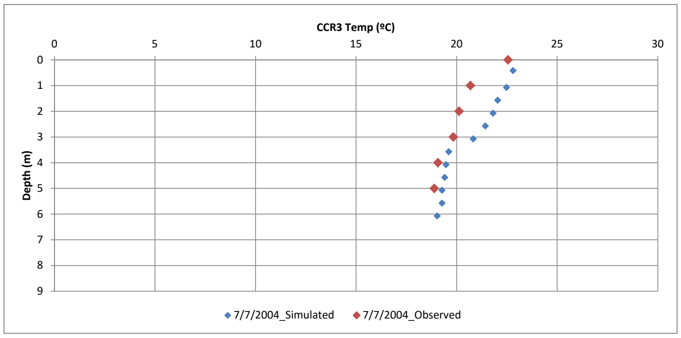

CCR2 Temp (ºC)
0 5 10 15 20 25 30
0 1 2 3 4 5 6 7 8 9
Depth (m)
5/24/2004_Simulated
5/24/2004_Observed

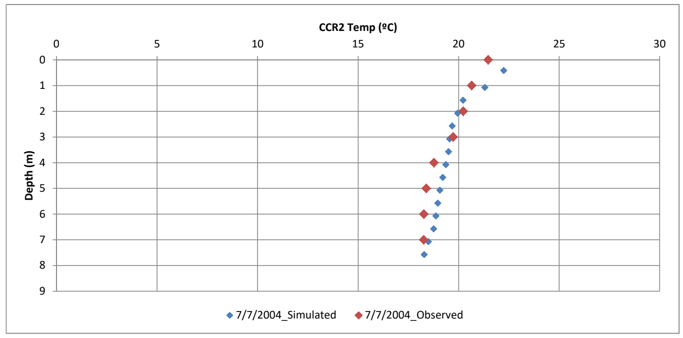

CCR3 Temp (ºC)
0 5 10 15 20 25 30
0 1 2 3 4 5 6 7 8 9
Depth (m)
6/9/2004_Simulated
6/9/2004_Observed

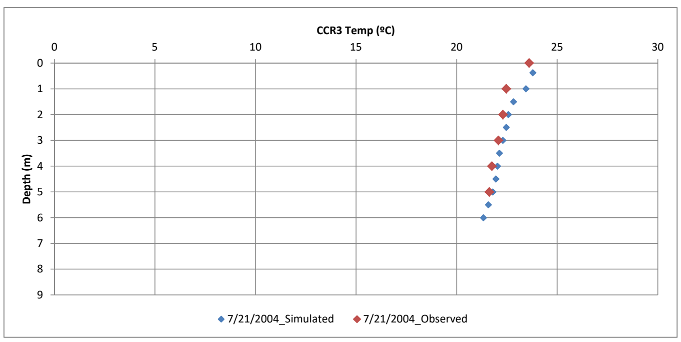

CCR2 Temp (ºC)
0 5 10 15 20 25 30
0 1 2 3 4 5 6 7 8 9
Depth (m)
6/9/2004_Simulated
6/9/2004_Observed

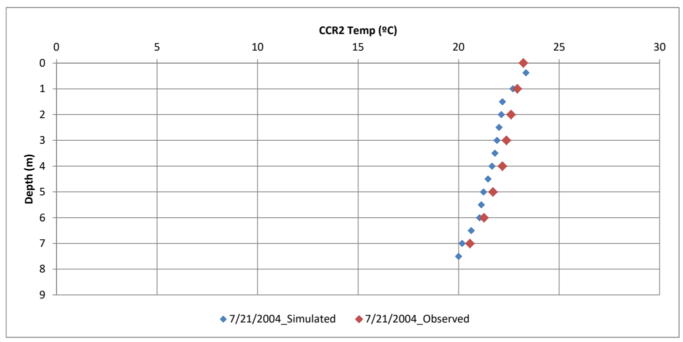

CCR3 Temp (ºC)
0 5 10 15 20 25 30
Depth (m)
0 1 2 3 4 5 6 7 8 9
6/23/2004_Simulated
6/23/2004_Observed

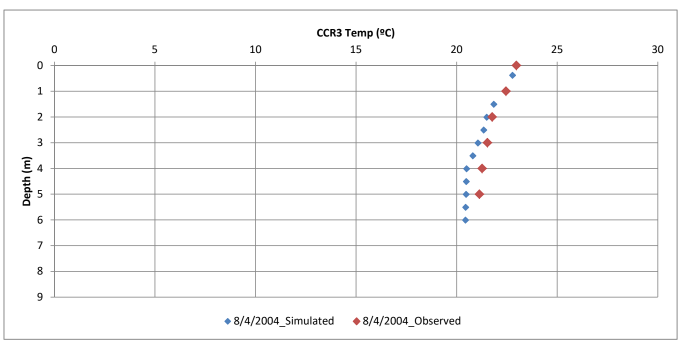

CCR2 Temp (ºC)
0 5 10 15 20 25 30
Depth (m)
0 1 2 3 4 5 6 7 8 9
6/23/2004_Simulated
6/23/2004_Observed

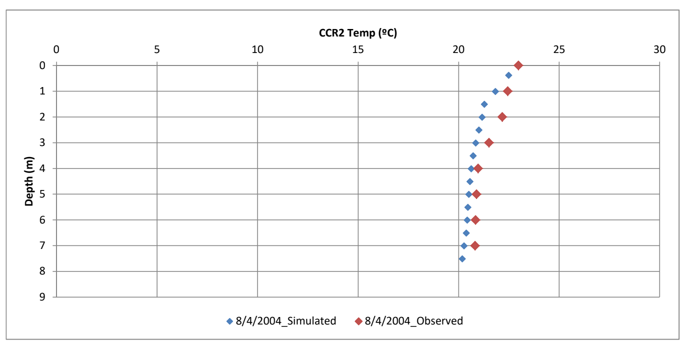

CCR3 Temp (ºC)
0 5 10 15 20 25 30
Depth (m)
0 1 2 3 4 5 6 7 8 9
7/7/2004_Simulated
7/7/2004_Observed

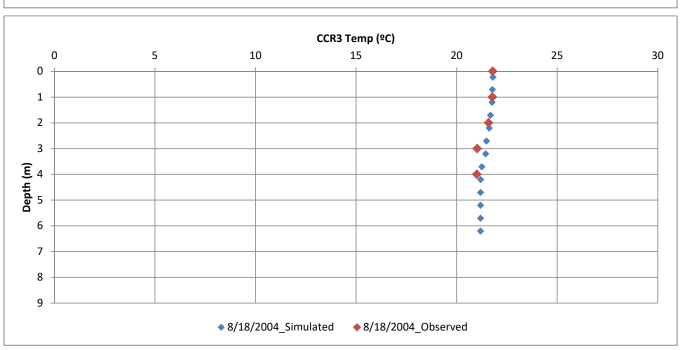

CCR2 Temp (ºC)
0 5 10 15 20 25 30
Depth (m)
0 1 2 3 4 5 6 7 8 9
7/7/2004_Simulated
7/7/2004_Observed

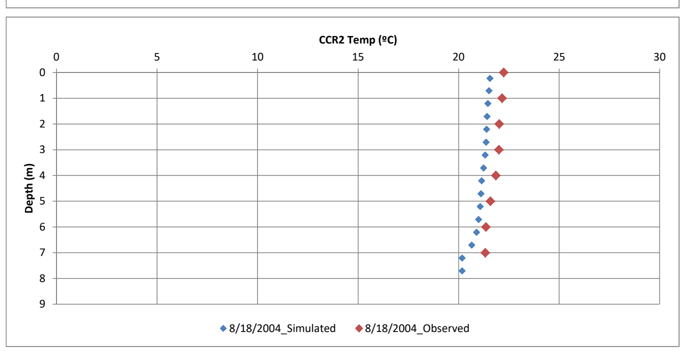

CCR3 Temp (ºC)
0 5 10 15 20 25 30
Depth (m)
0 1 2 3 4 5 6 7 8 9
7/21/2004_Simulated
7/21/2004_Observed

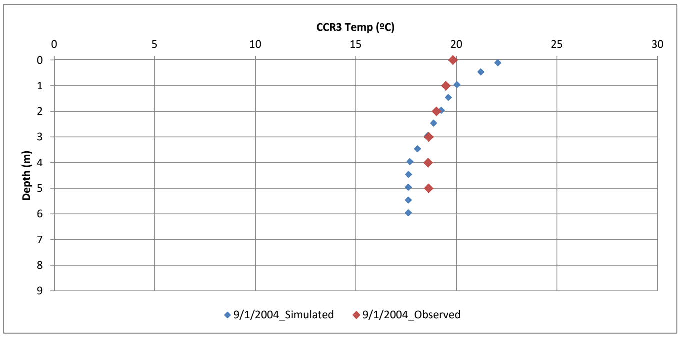

CCR2 Temp (ºC)
0 5 10 15 20 25 30
Depth (m)
0 1 2 3 4 5 6 7 8 9
7/21/2004_Simulated
7/21/2004_Observed

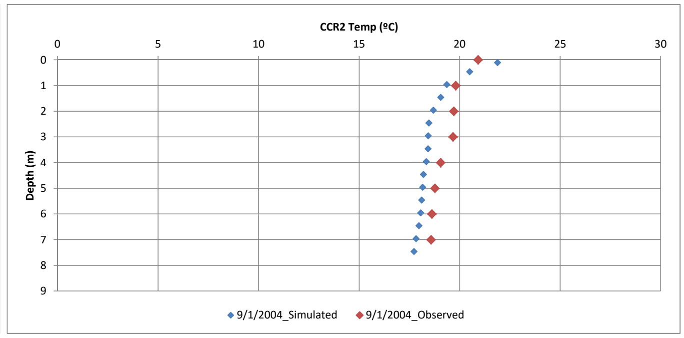

CCR3 Temp (ºC)
0 5 10 15 20 25 30
Depth (m)
0 1 2 3 4 5 6 7 8 9
8/4/2004_Simulated
8/4/2004_Observed

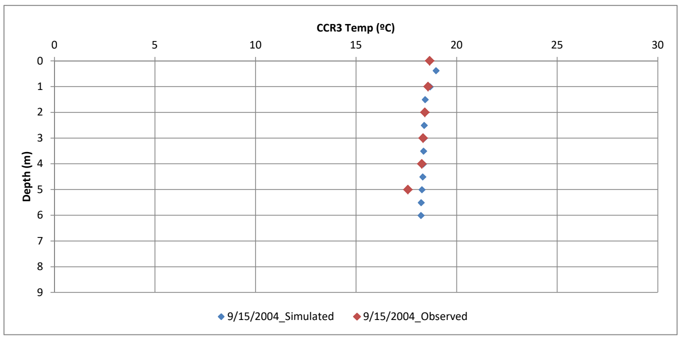

CCR2 Temp (ºC)
0 5 10 15 20 25 30
Depth (m)
0 1 2 3 4 5 6 7 8 9
8/4/2004_Simulated
8/4/2004_Observed

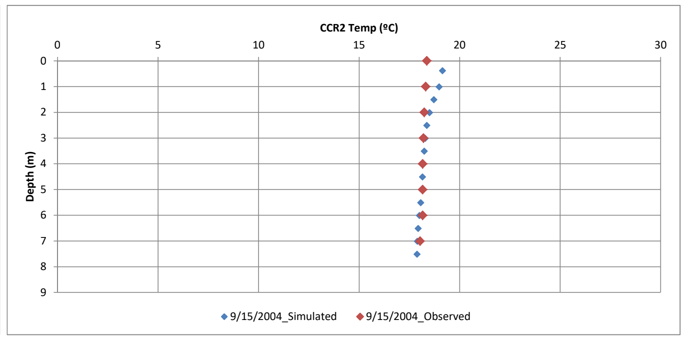

CCR3 Temp (ºC)
0 5 10 15 20 25 30
Depth (m)
0 1 2 3 4 5 6 7 8 9
8/18/2004_Simulated
8/18/2004_Observed

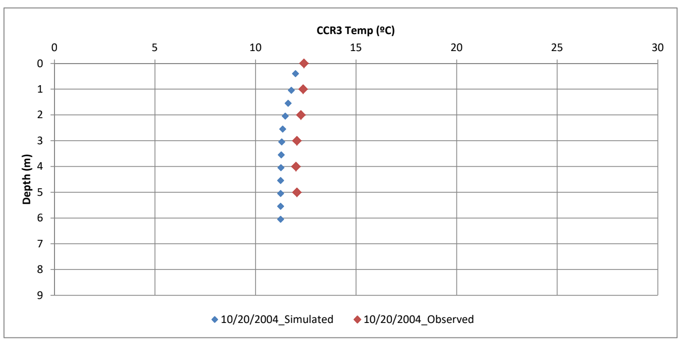

CCR2 Temp (ºC)
0 5 10 15 20 25 30
Depth (m)
0 1 2 3 4 5 6 7 8 9
8/18/2004_Simulated
8/18/2004_Observed

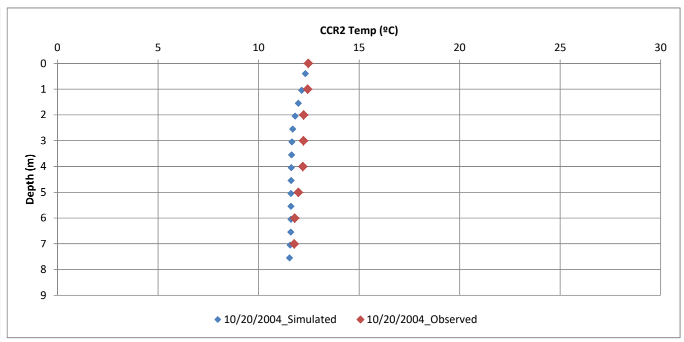

CCR3 Temp (ºC)
Depth (m)
9/1/2004_Simulated
9/1/2004_Observed

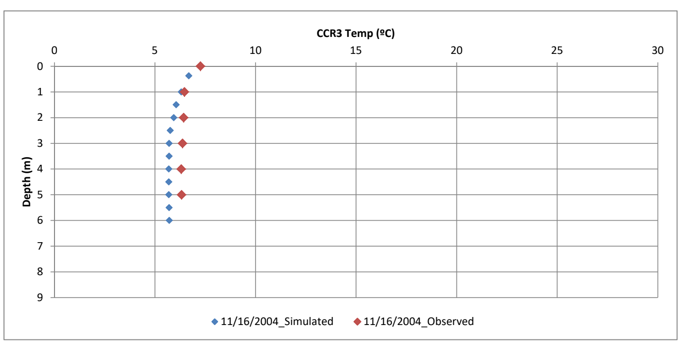

CCR2 Temp (ºC)
Depth (m)
9/1/2004_Simulated
9/1/2004_Observed

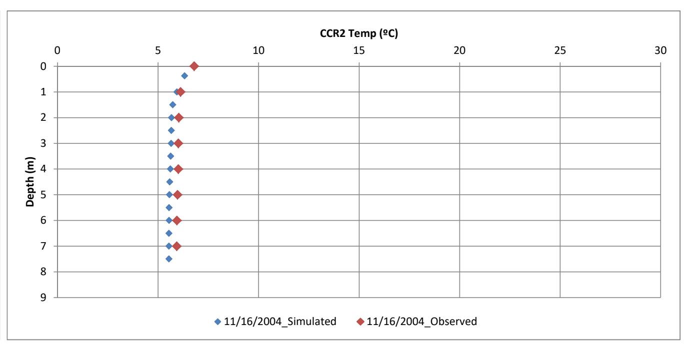

CCR3 Temp (ºC)
Depth (m)
9/15/2004_Simulated
9/15/2004_Observed

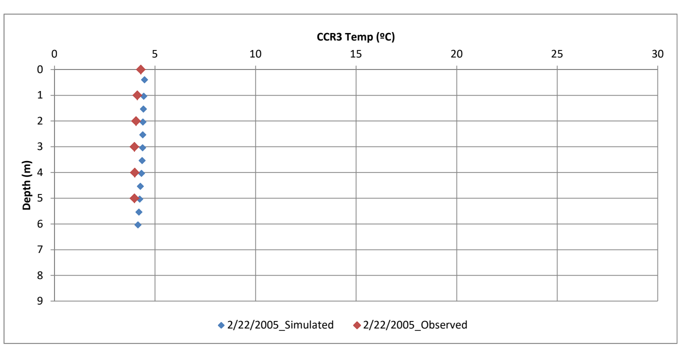

CCR2 Temp (ºC)
Depth (m)
9/15/2004_Simulated
9/15/2004_Observed

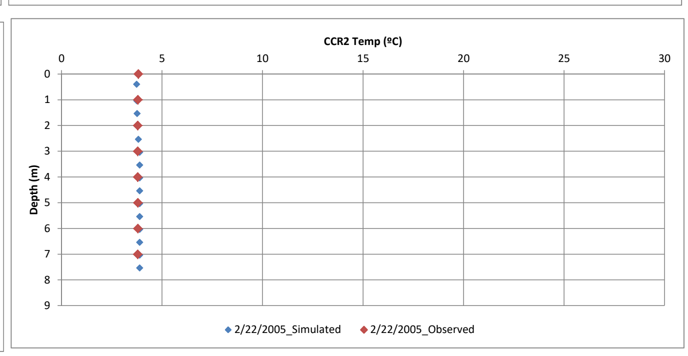

CCR3 Temp (ºC)
Depth (m)
10/20/2004_Simulated
10/20/2004_Observed

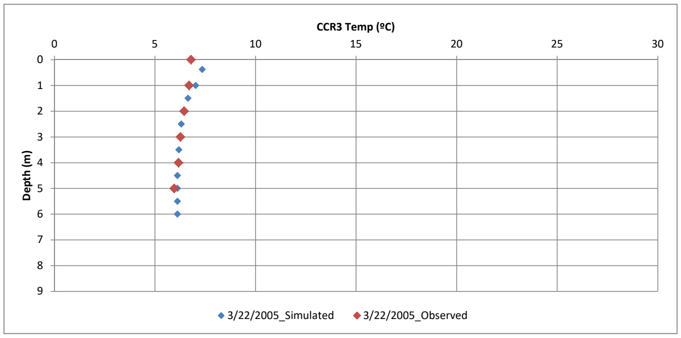

CCR2 Temp (ºC)
Depth (m)
10/20/2004_Simulated
10/20/2004_Observed

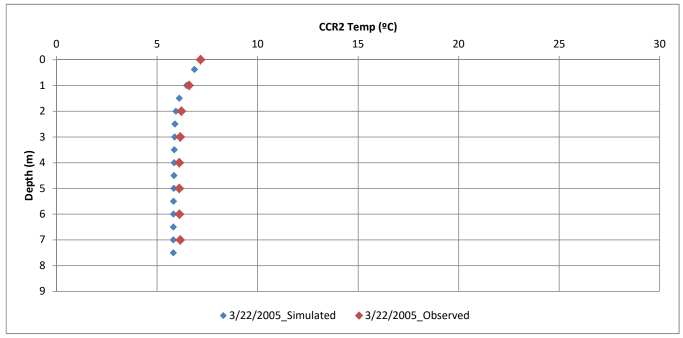

CCR3 Temp (ºC)
Depth (m)
11/16/2004_Simulated
11/16/2004_Observed

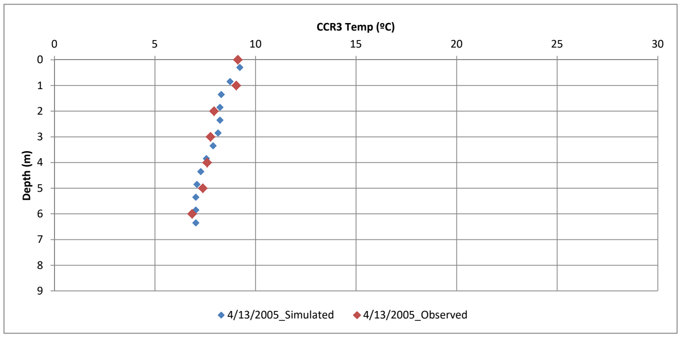

CCR2 Temp (ºC)
Depth (m)
11/16/2004_Simulated
11/16/2004_Observed


CCR3 Temp (ºC)
Depth (m)
2/22/2005_Simulated
2/22/2005_Observed


CCR2 Temp (ºC)
Depth (m)
2/22/2005_Simulated
2/22/2005_Observed


CCR3 Temp (ºC)
0 5 10 15 20 25 30
Depth (m)
0 1 2 3 4 5 6 7 8 9
3/22/2005_Simulated
3/22/2005_Observed


CCR2 Temp (ºC)
0 5 10 15 20 25 30
Depth (m)
0 1 2 3 4 5 6 7 8 9
3/22/2005_Simulated
3/22/2005_Observed


CCR3 Temp (ºC)
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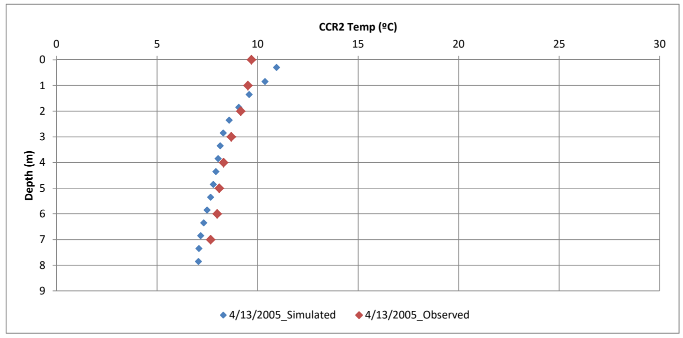
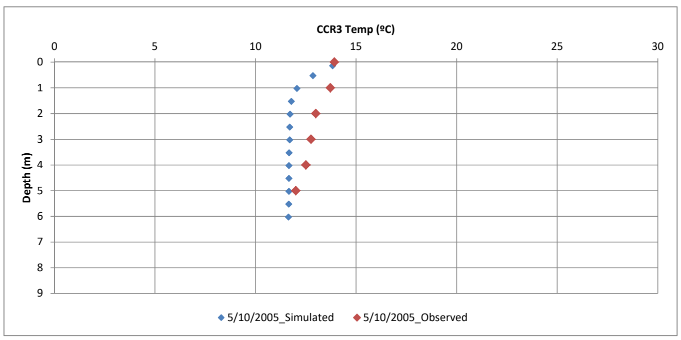
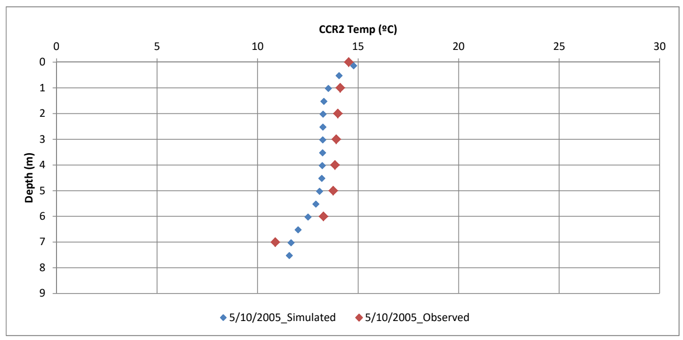
Depth (m)
0 1 2 3 4 5 6 7 8 9
4/13/2005_Simulated
4/13/2005_Observed


CCR2 Temp (ºC)
0 5 10 15 20 25 30
Depth (m)
0 1 2 3 4 5 6 7 8 9
4/13/2005_Simulated
4/13/2005_Observed


CCR3 Temp (ºC)
0 5 10 15 20 25 30
Depth (m)
0 1 2 3 4 5 6 7 8 9
5/10/2005_Simulated
5/10/2005_Observed


CCR2 Temp (ºC)
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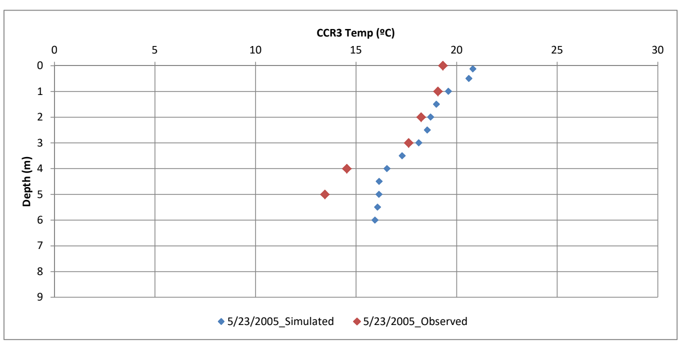
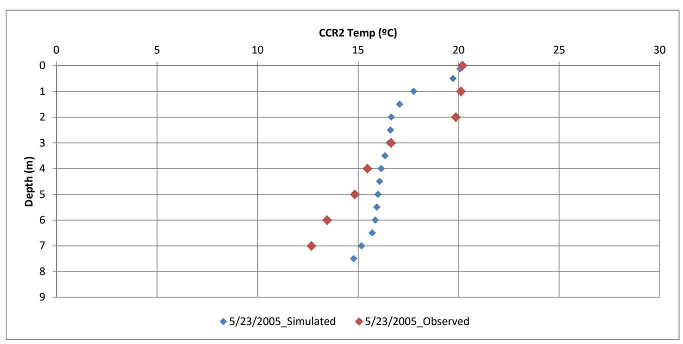
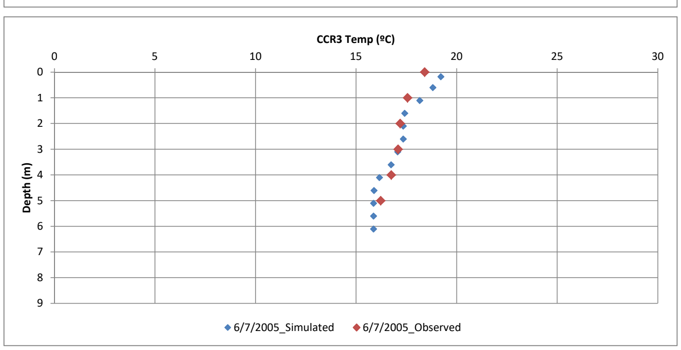
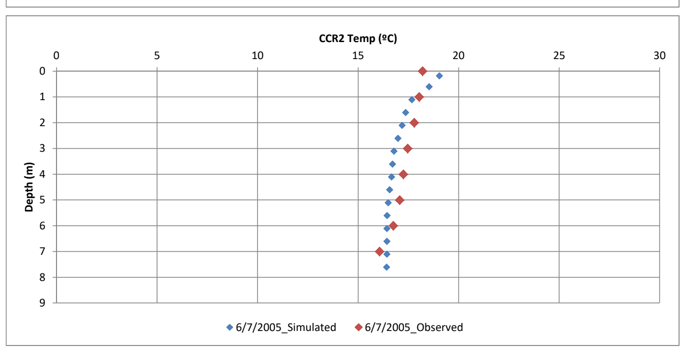
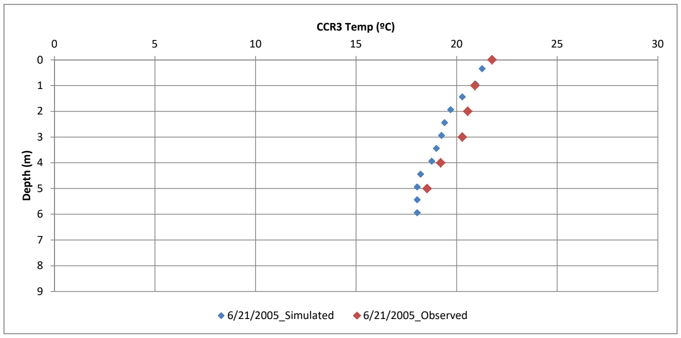
Depth (m)
0 1 2 3 4 5 6 7 8 9
5/10/2005_Simulated
5/10/2005_Observed

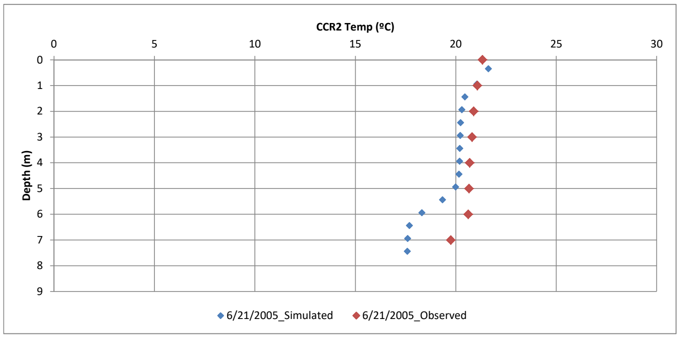

CCR3 Temp (ºC)
0 5 10 15 20 25 30
Depth (m)
0 1 2 3 4 5 6 7 8 9
5/23/2005_Simulated
5/23/2005_Observed

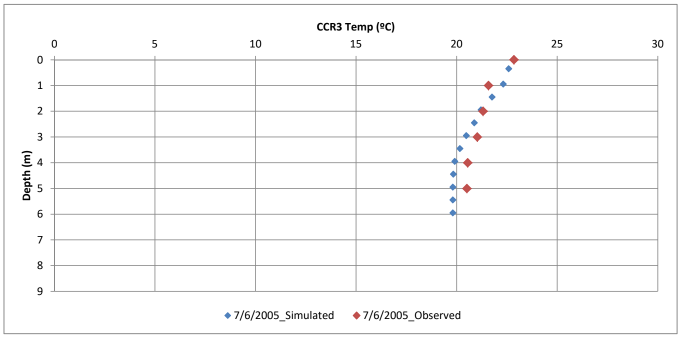

CCR2 Temp (ºC)
0 5 10 15 20 25 30
Depth (m)
0 1 2 3 4 5 6 7 8 9
5/23/2005_Simulated
5/23/2005_Observed

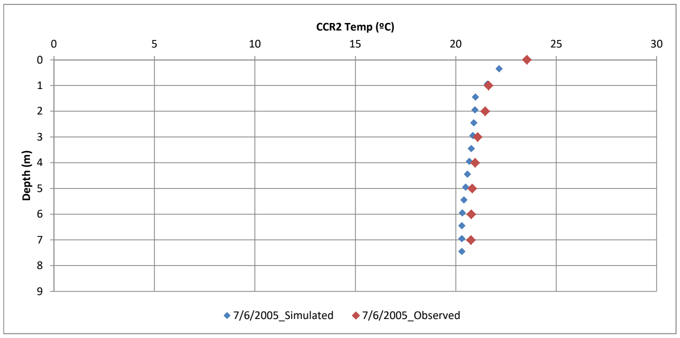

CCR3 Temp (ºC)
0 5 10 15 20 25 30
Depth (m)
0 1 2 3 4 5 6 7 8 9
6/7/2005_Simulated
6/7/2005_Observed

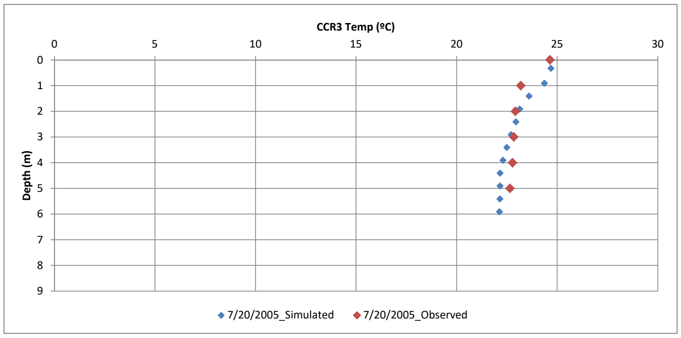

CCR2 Temp (ºC)
0 5 10 15 20 25 30
Depth (m)
0 1 2 3 4 5 6 7 8 9
6/7/2005_Simulated
6/7/2005_Observed

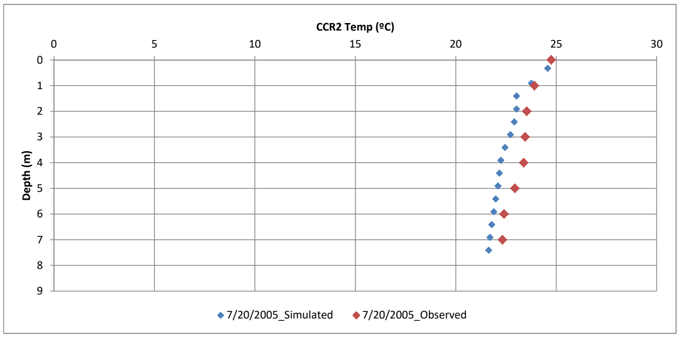

CCR3 Temp (ºC)
Depth (m)
6/21/2005_Simulated
6/21/2005_Observed

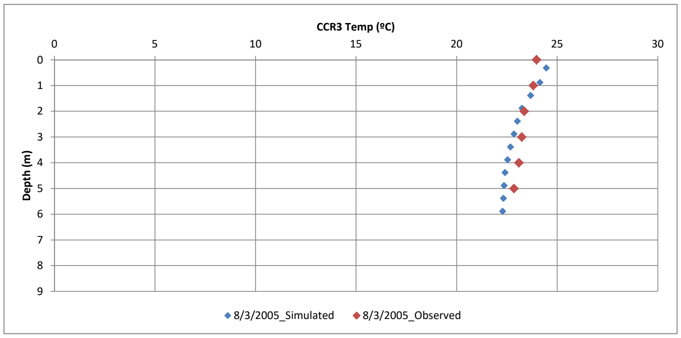

CCR2 Temp (ºC)
Depth (m)
6/21/2005_Simulated
6/21/2005_Observed


CCR3 Temp (ºC)
Depth (m)
7/6/2005_Simulated
7/6/2005_Observed


CCR2 Temp (ºC)
Depth (m)
7/6/2005_Simulated
7/6/2005_Observed


CCR3 Temp (ºC)
Depth (m)
7/20/2005_Simulated
7/20/2005_Observed


CCR2 Temp (ºC)
Depth (m)
7/20/2005_Simulated
7/20/2005_Observed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Depth (m)
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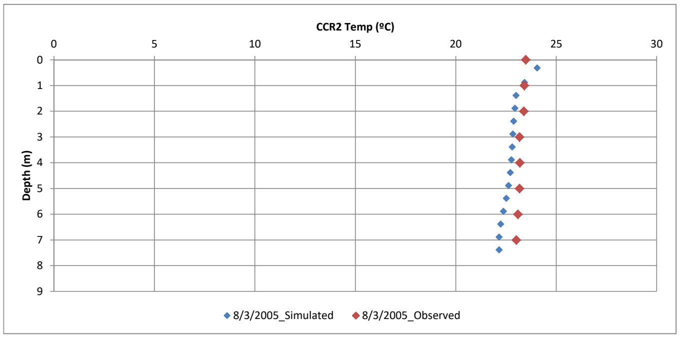
8/3/2005_Observed


CCR2 Temp (ºC)
Depth (m)
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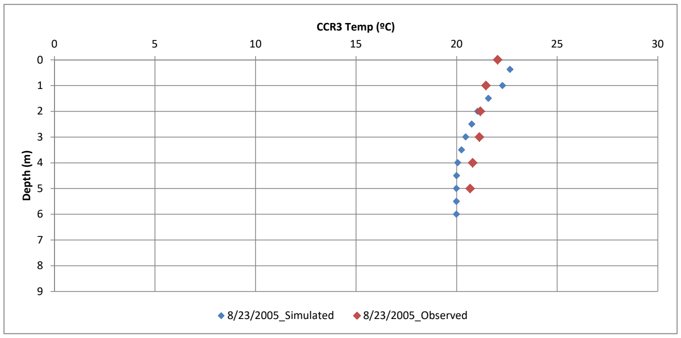
8/3/2005_Observed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Depth (m)
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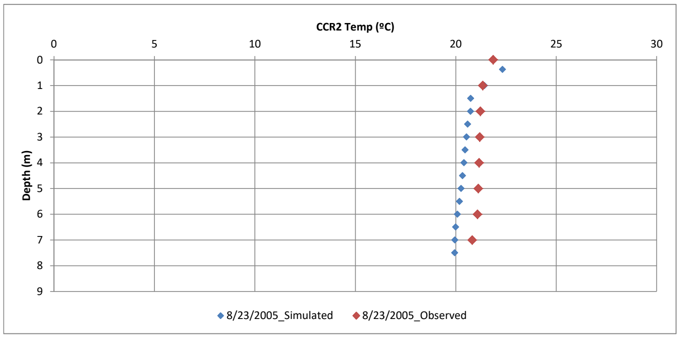
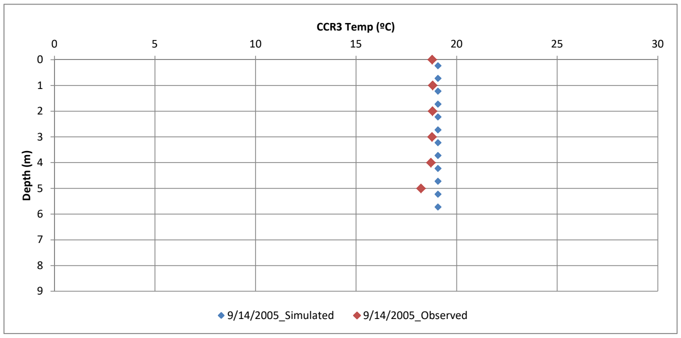
8/23/2005_Observed


CCR2 Temp (ºC)
Depth (m)
8/23/2005_Simulated
8/23/2005_Observed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Depth (m)
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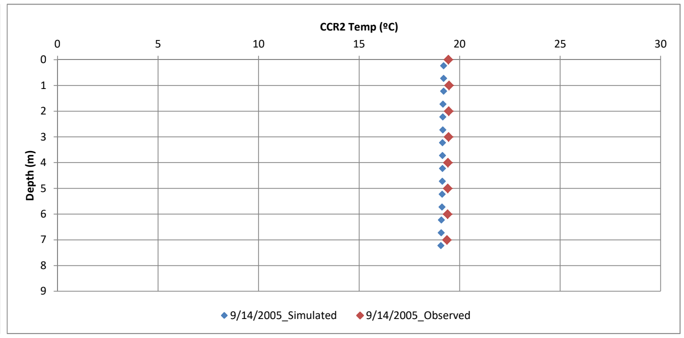
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Depth (m)
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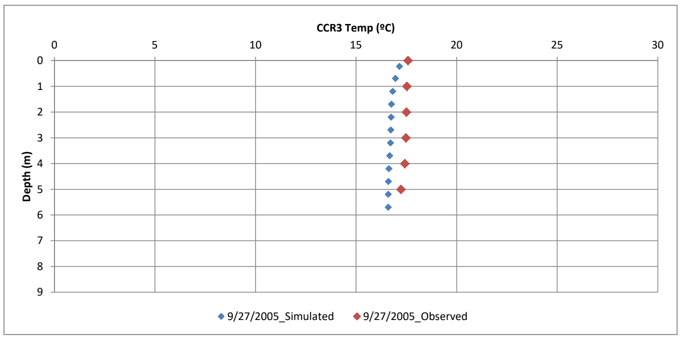
9/14/2005_Observed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Depth (m)
9/27/2005_Simulated
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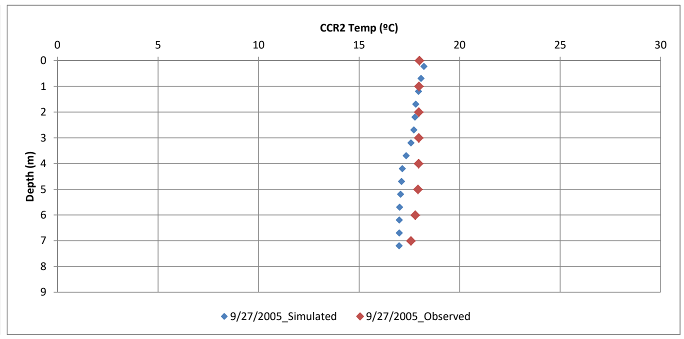
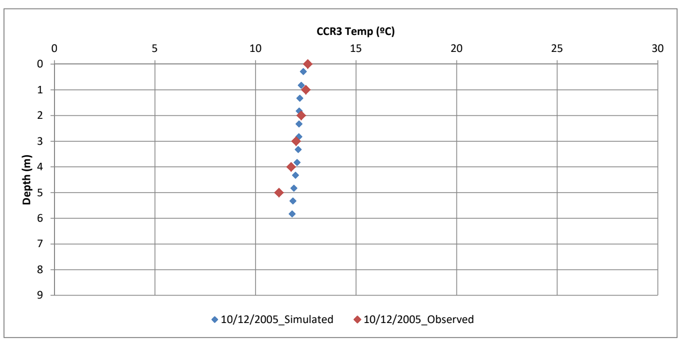

CCR2 Temp (ºC)
Depth (m)
9/27/2005_Simulated
9/27/2005_Observed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Depth (m)
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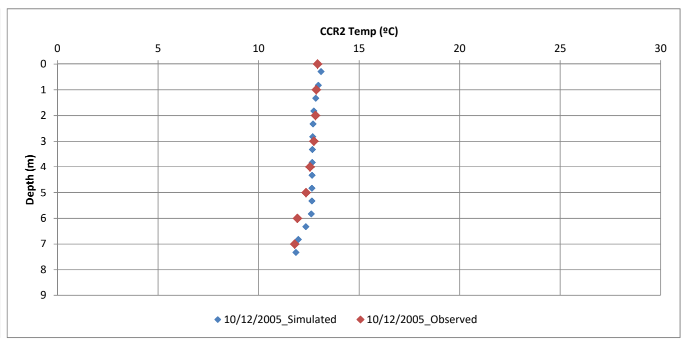
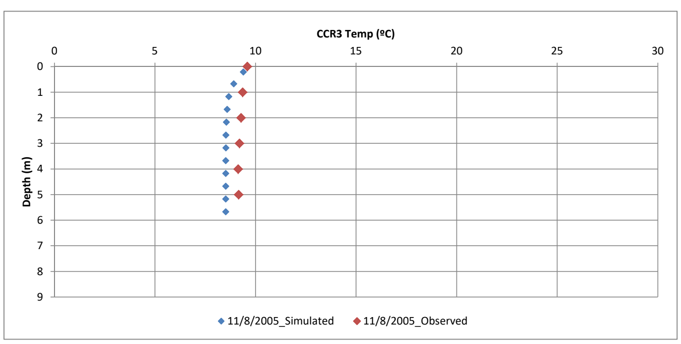
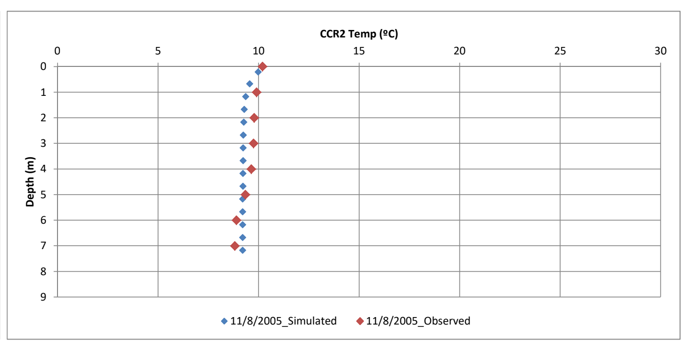
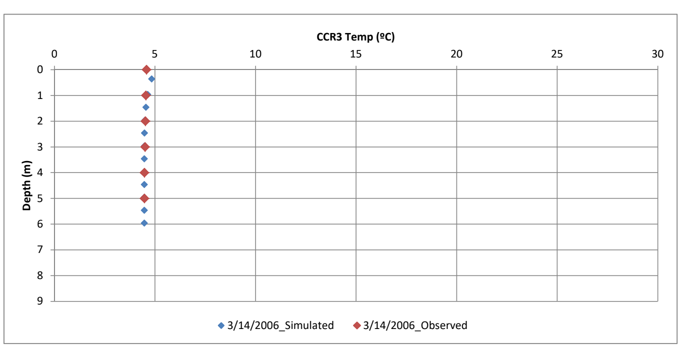

CCR2 Temp (ºC)
Depth (m)
10/12/2005_Simulated
10/12/2005_Observed


CCR3 Temp (ºC)
Depth (m)
11/8/2005_Simulated
11/8/2005_Observed


CCR2 Temp (ºC)
Depth (m)
11/8/2005_Simulated
11/8/2005_Observed


CCR3 Temp (ºC)
Depth (m)
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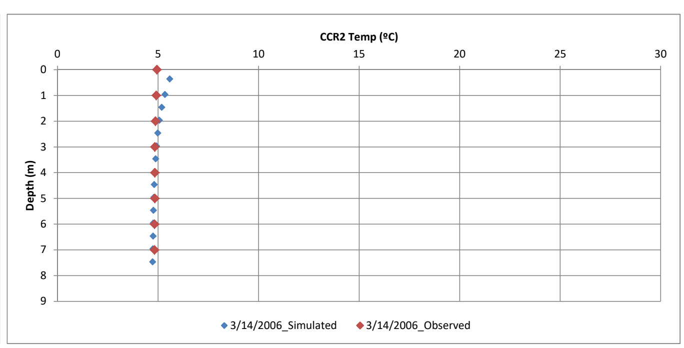
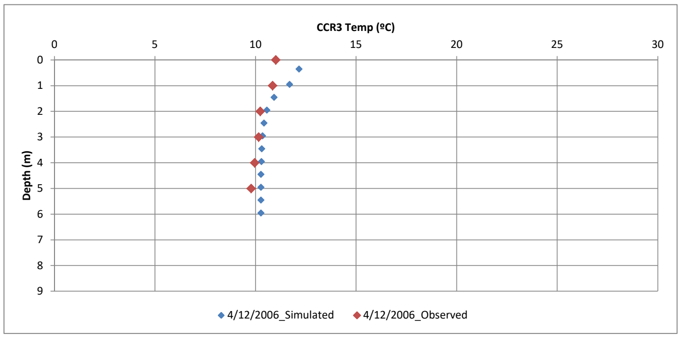

CCR2 Temp (ºC)
Depth (m)
3/14/2006_Simulated
3/14/2006_Observed


CCR3 Temp (ºC)
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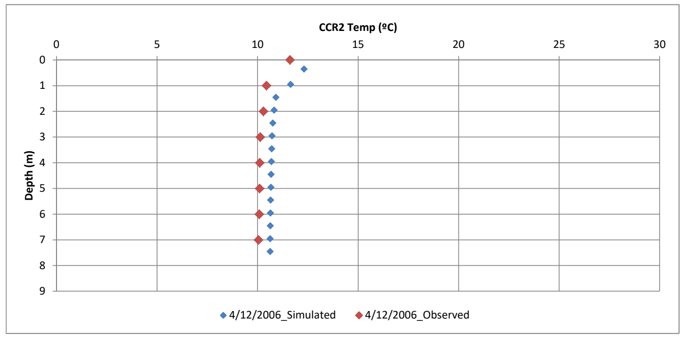
0 1 2 3 4 5 6 7 8 9
Depth (m)
4/12/2006_Simulated
4/12/2006_Observed


CCR2 Temp (ºC)
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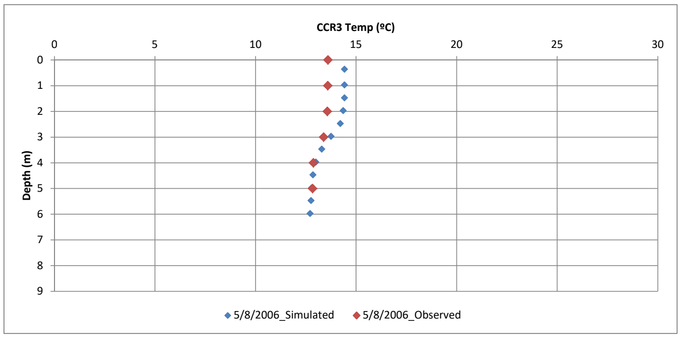
0 1 2 3 4 5 6 7 8 9
Depth (m)
4/12/2006_Simulated
4/12/2006_Observed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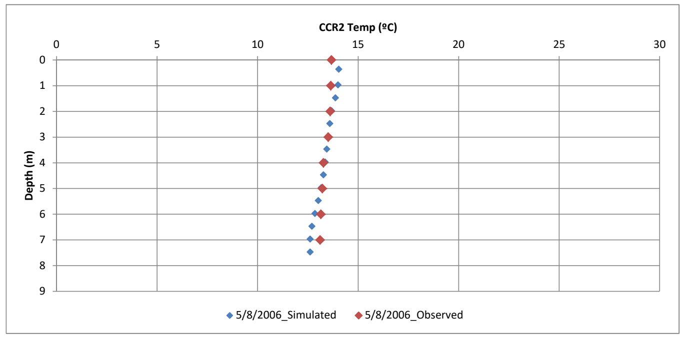
0 1 2 3 4 5 6 7 8 9
Depth (m)
5/8/2006_Simulated
5/8/2006_Observed


CCR2 Temp (ºC)
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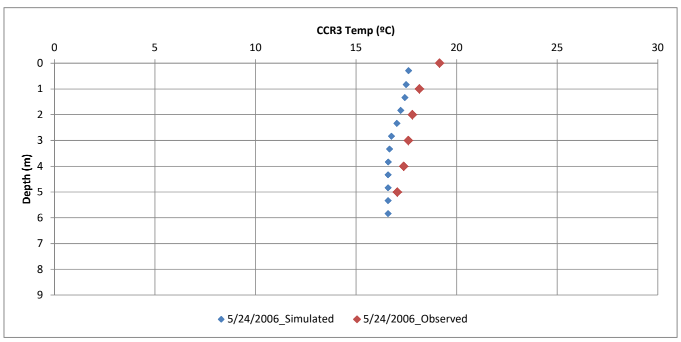
0 1 2 3 4 5 6 7 8 9
Depth (m)
5/8/2006_Simulated
5/8/2006_Observed


CCR3 Temp (ºC)
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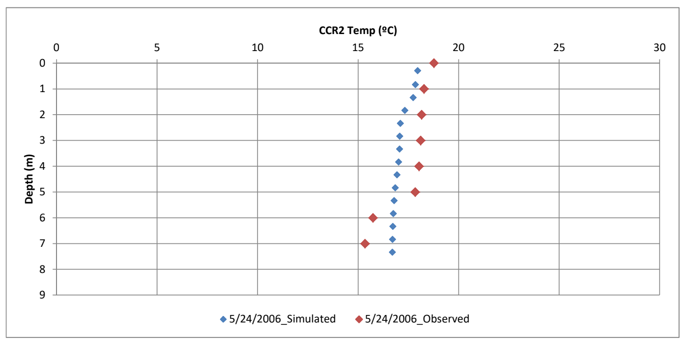
0 1 2 3 4 5 6 7 8 9
Depth (m)
5/24/2006_Simulated
5/24/2006_Observed


CCR2 Temp (ºC)
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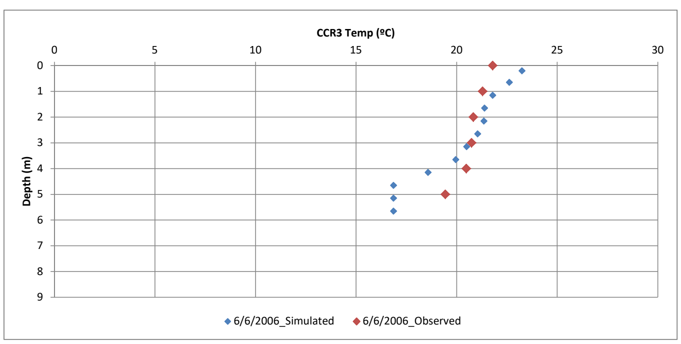
0 1 2 3 4 5 6 7 8 9
Depth (m)
5/24/2006_Simulated
5/24/2006_Observed

x


CCR3 Temp (ºC)
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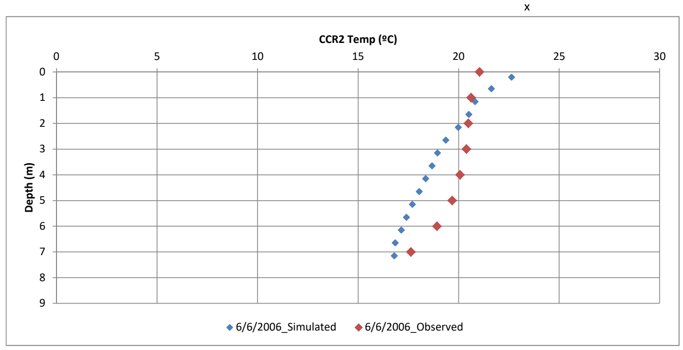
0 1 2 3 4 5 6 7 8 9
Depth (m)
6/6/2006_Simulated
6/6/2006_Observed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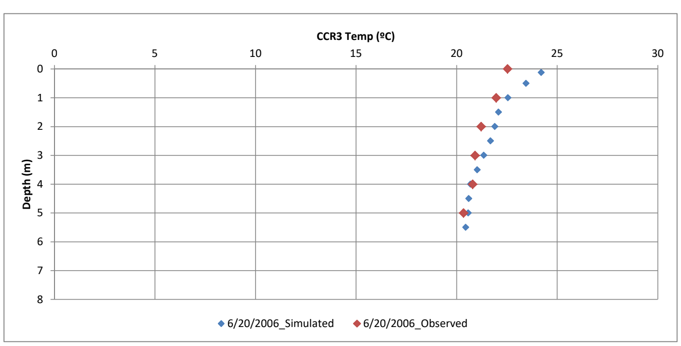
Depth (m)
6/6/2006_Simulated
6/6/2006_Observed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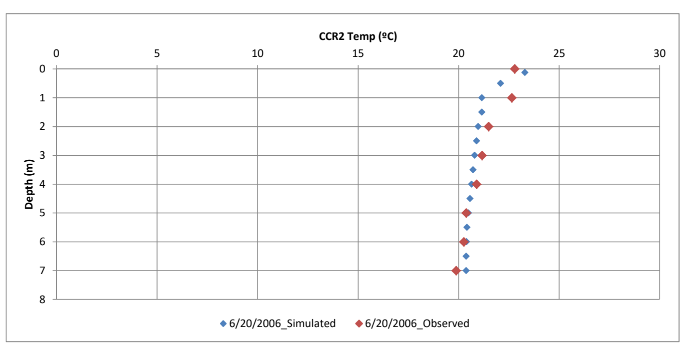
Depth (m)
6/20/2006_Simulated
6/20/2006_Observed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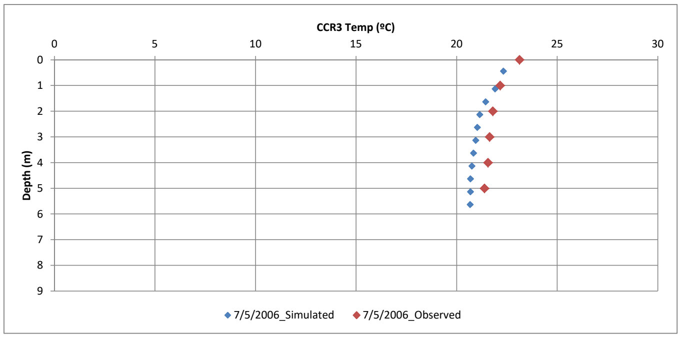
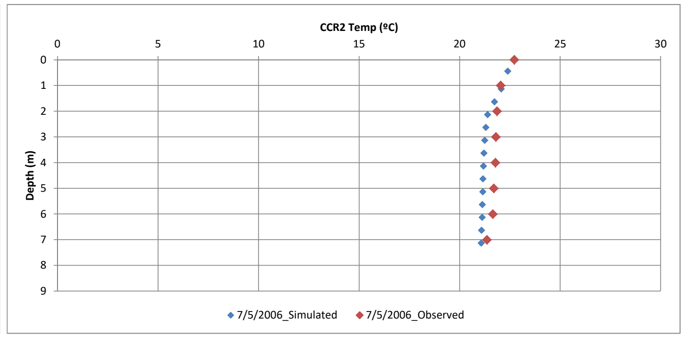
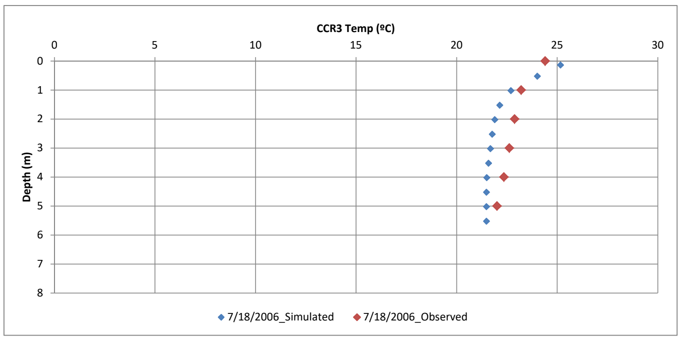
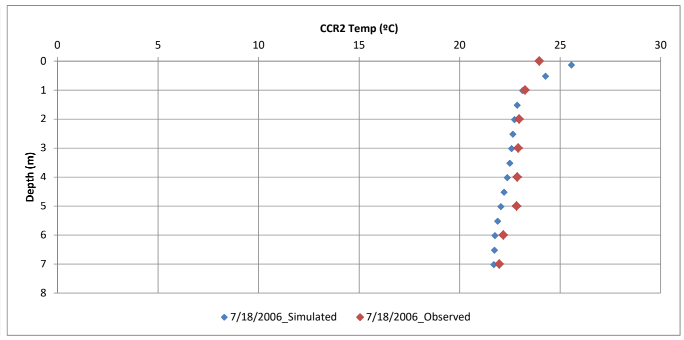
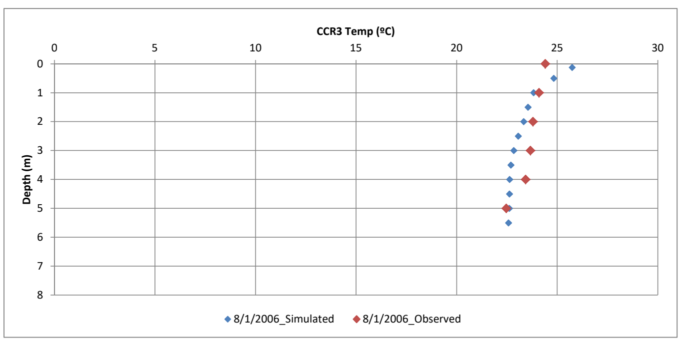
0 1 2 3 4 5 6 7 8
Depth (m)
6/20/2006_Simulated
6/20/2006_Observed

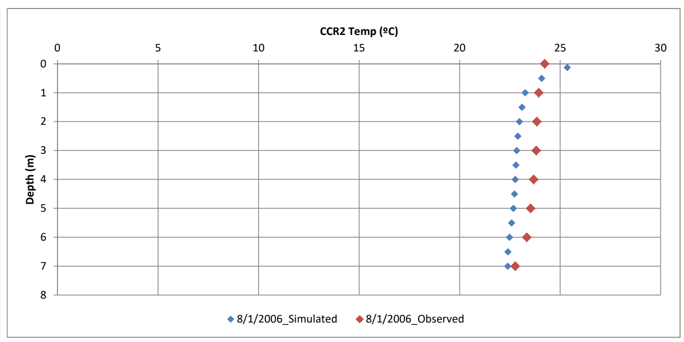

CCR3 Temp (ºC)
Depth (m)
7/5/2006_Simulated
7/5/2006_Observed

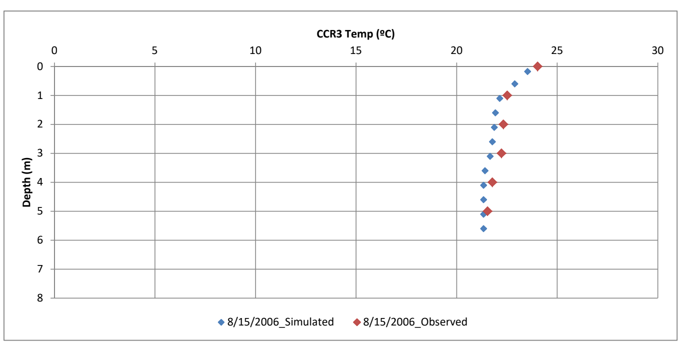

CCR2 Temp (ºC)
Depth (m)
7/5/2006_Simulated
7/5/2006_Observed

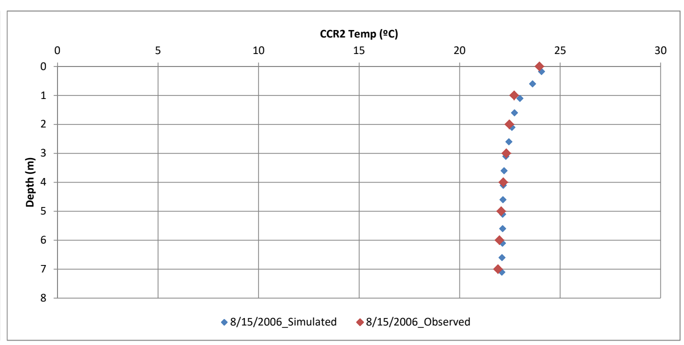

CCR3 Temp (ºC)
Depth (m)
7/18/2006_Simulated
7/18/2006_Observed

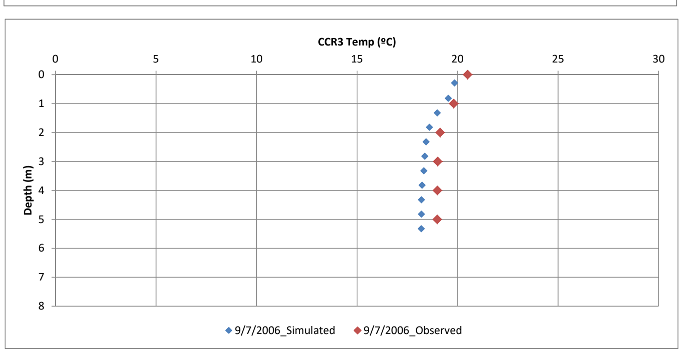

CCR2 Temp (ºC)
Depth (m)
7/18/2006_Simulated
7/18/2006_Observed

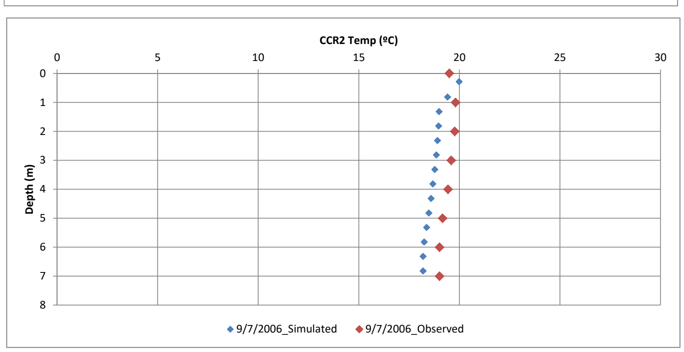

CCR3 Temp (ºC)
Depth (m)
8/1/2006_Simulated
8/1/2006_Observed

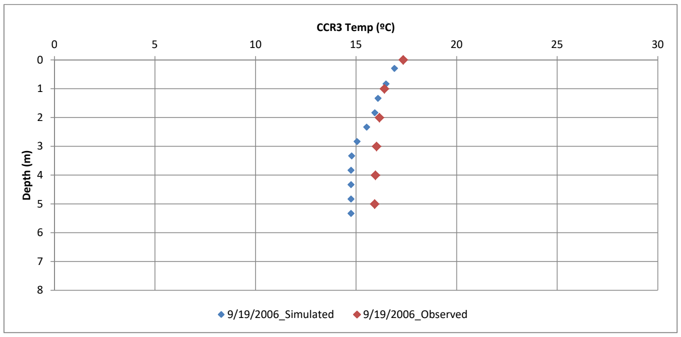

CCR2 Temp (ºC)
Depth (m)
8/1/2006_Simulated
8/1/2006_Observed

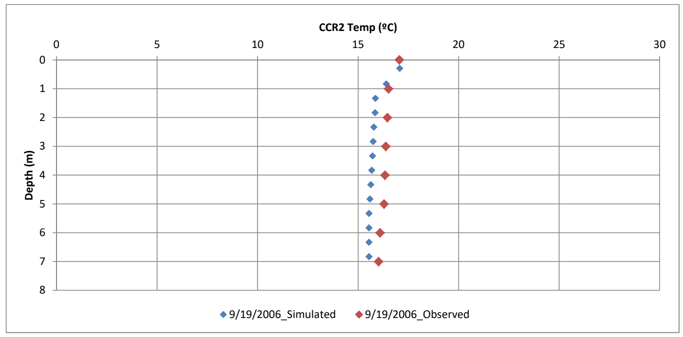

CCR3 Temp (ºC)
Depth (m)
8/15/2006_Simulated
8/15/2006_Observed

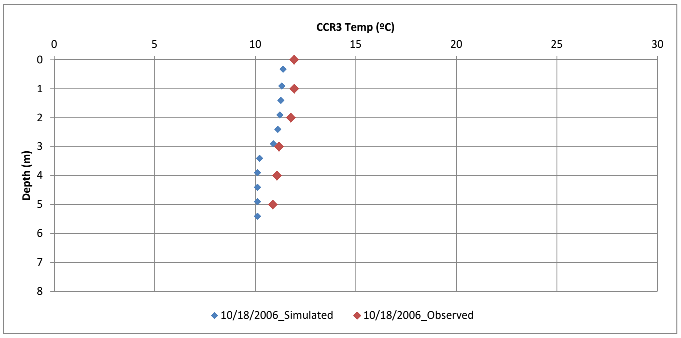

CCR2 Temp (ºC)
Depth (m)
8/15/2006_Simulated
8/15/2006_Observed

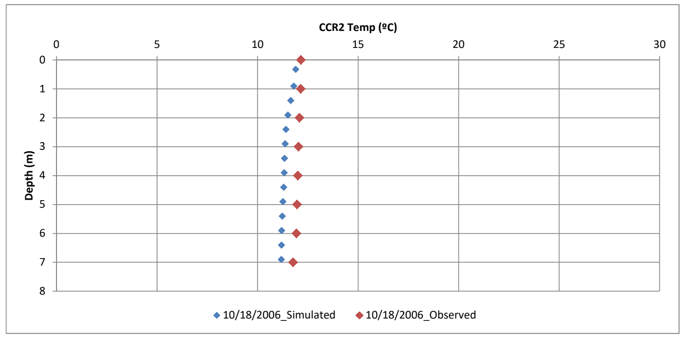

CCR3 Temp (ºC)
Depth (m)
9/7/2006_Simulated
9/7/2006_Observed

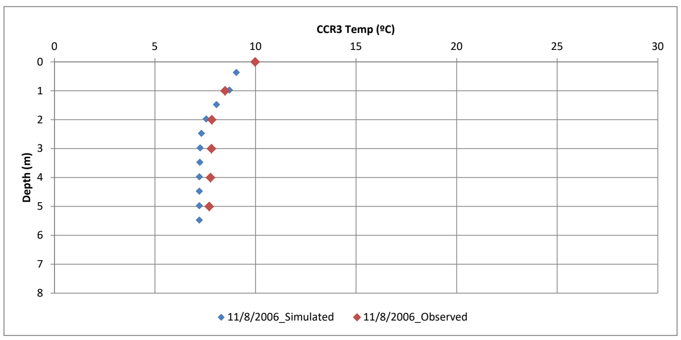

CCR2 Temp (ºC)
Depth (m)
9/7/2006_Simulated
9/7/2006_Observed

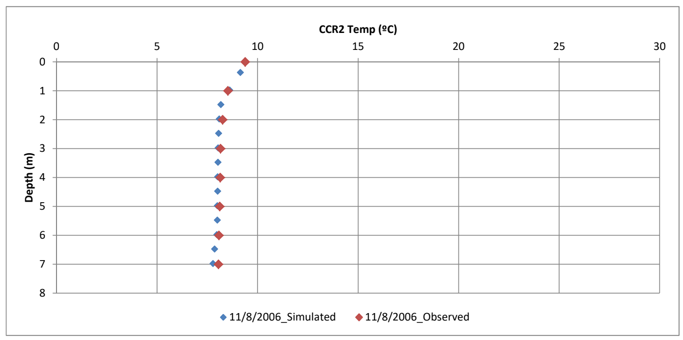

CCR3 Temp (ºC)
Depth (m)
9/19/2006_Simulated
9/19/2006_Observed

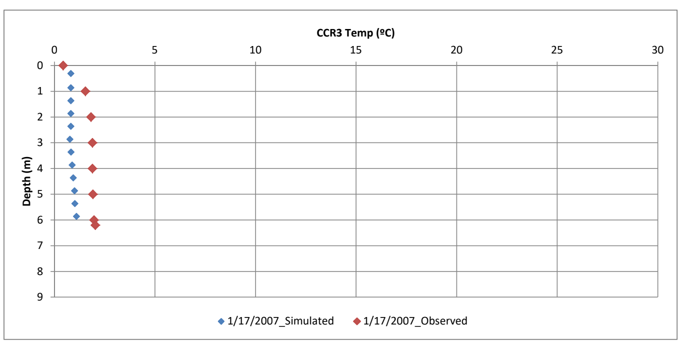

CCR2 Temp (ºC)
Depth (m)
9/19/2006_Simulated
9/19/2006_Observed

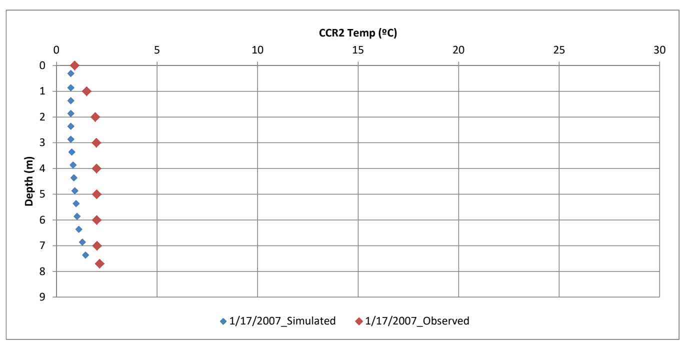

CCR3 Temp (ºC)
Depth (m)
10/18/2006_Simulated
10/18/2006_Observed

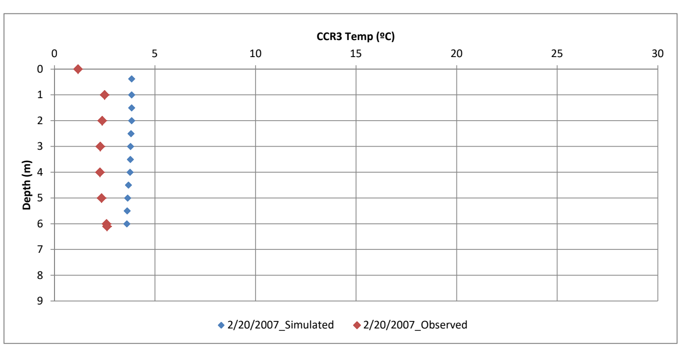

CCR2 Temp (ºC)
Depth (m)
10/18/2006_Simulated
10/18/2006_Observed

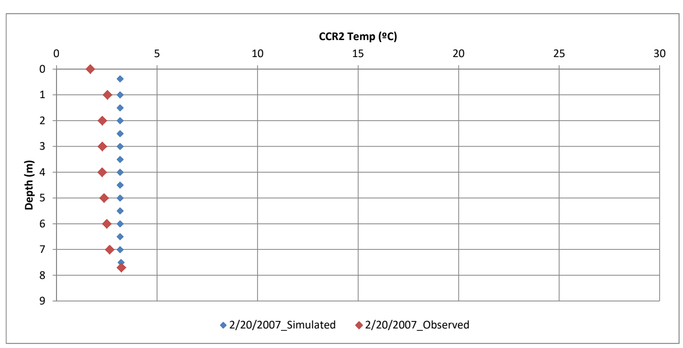

CCR3 Temp (ºC)
Depth (m)
11/8/2006_Simulated
11/8/2006_Observed

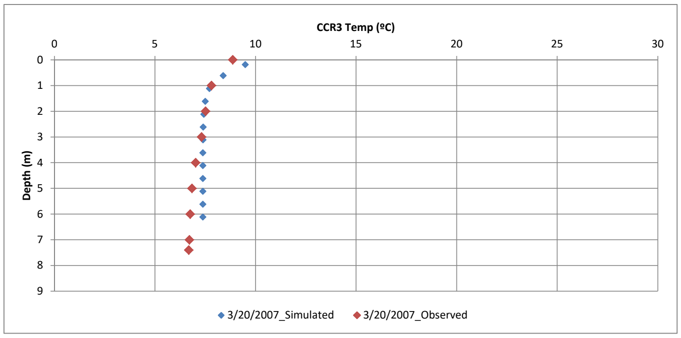

CCR2 Temp (ºC)
Depth (m)
11/8/2006_Simulated
11/8/2006_Observed


CCR3 Temp (ºC)
Depth (m)
1/17/2007_Simulated
1/17/2007_Observed


CCR2 Temp (ºC)
Depth (m)
1/17/2007_Simulated
1/17/2007_Observed


CCR3 Temp (ºC)
Depth (m)
2/20/2007_Simulated
2/20/2007_Observed


CCR2 Temp (ºC)
Depth (m)
2/20/2007_Simulated
2/20/2007_Observed


CCR3 Temp (ºC)
Depth (m)
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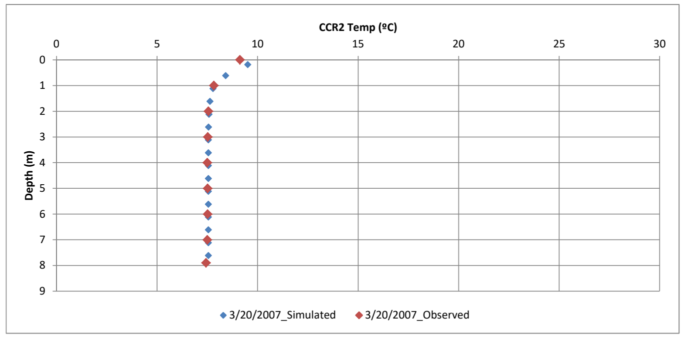
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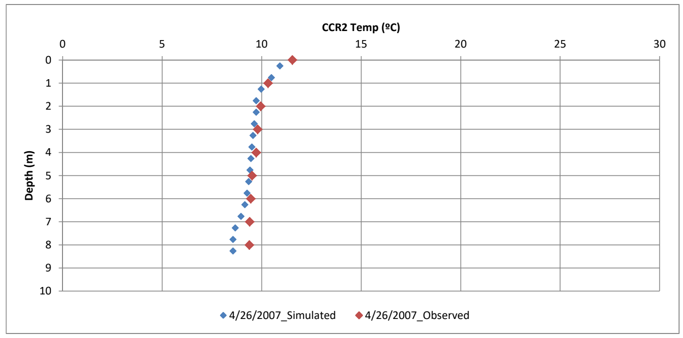
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Depth (m)
4/26/2007_Simulated
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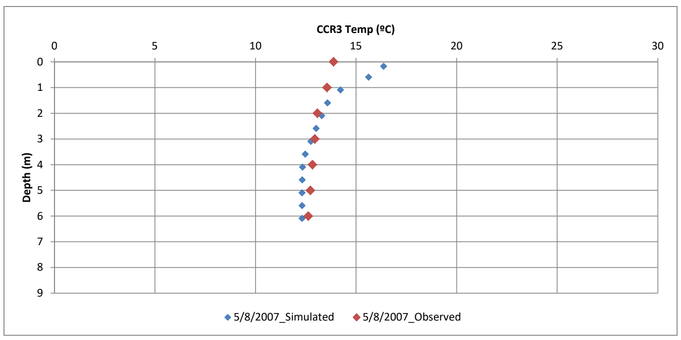
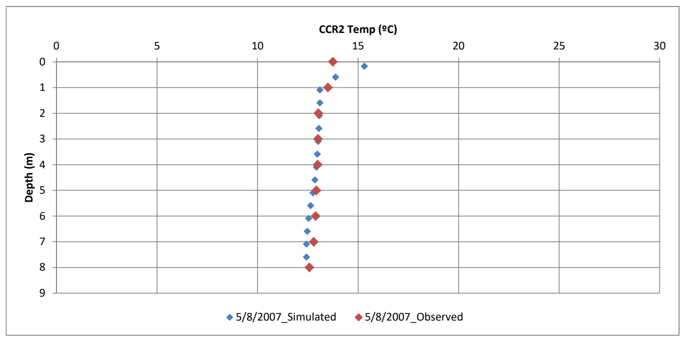
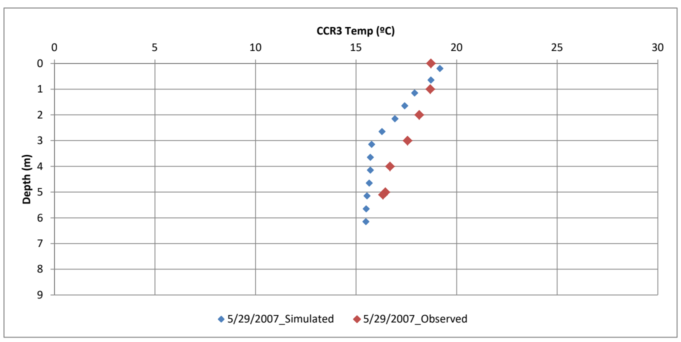
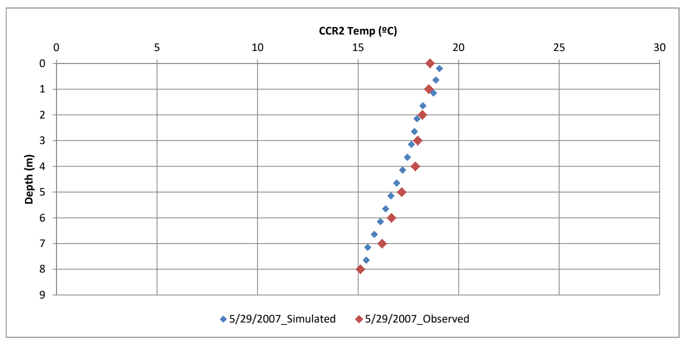
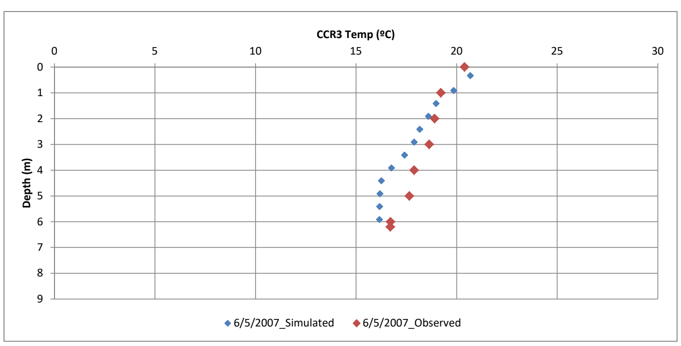

CCR3 Temp (ºC)
Depth (m)
5/8/2007_Simulated
5/8/2007_Observed


CCR2 Temp (ºC)
Depth (m)
5/8/2007_Simulated
5/8/2007_Observed


CCR3 Temp (ºC)
Depth (m)
5/29/2007_Simulated
5/29/2007_Observed


CCR2 Temp (ºC)
Depth (m)
5/29/2007_Simulated
5/29/2007_Observed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Depth (m)
6/5/2007_Simulated
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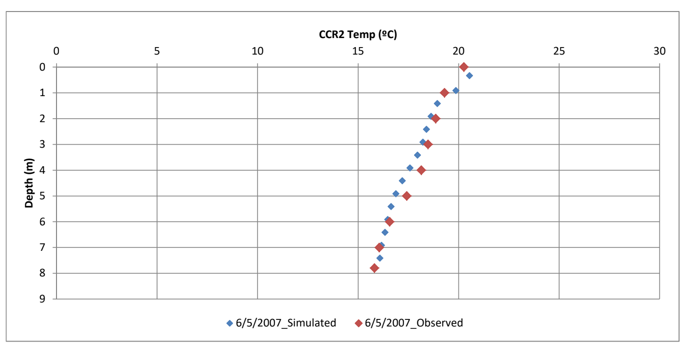
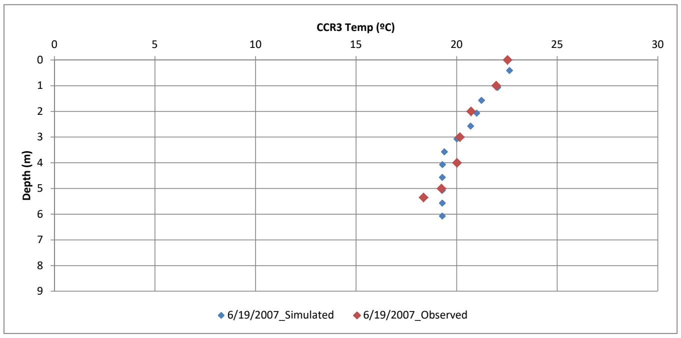
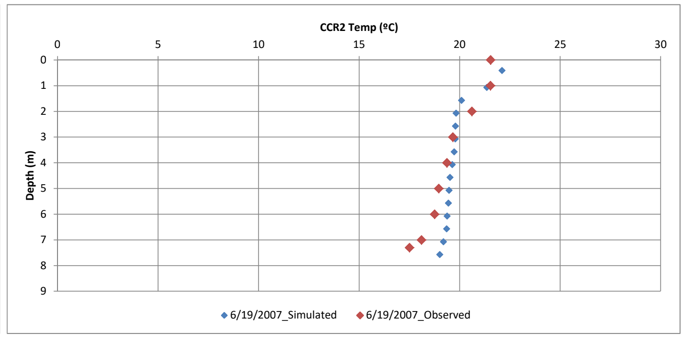
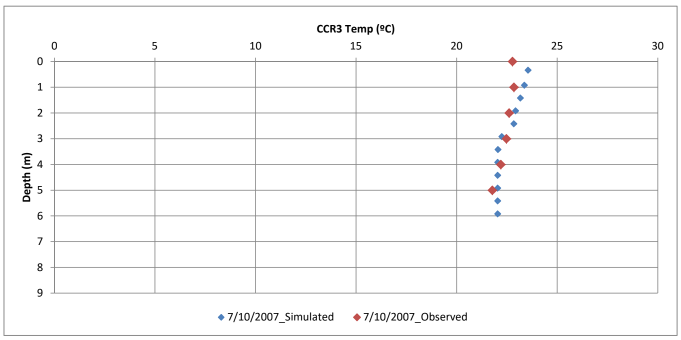
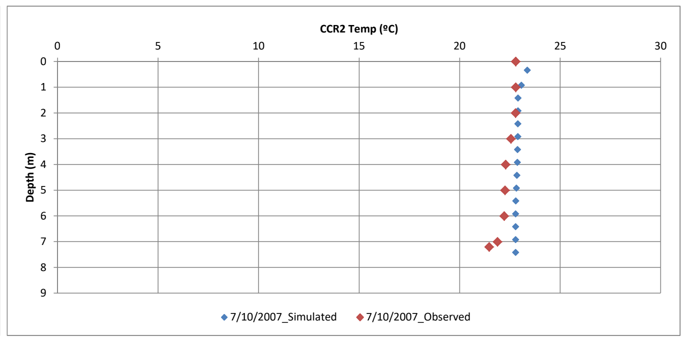
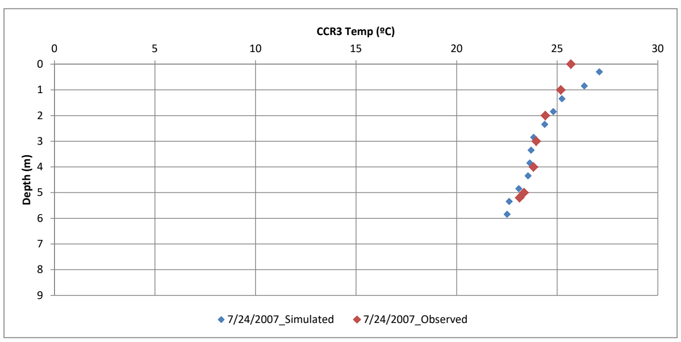

CCR2 Temp (ºC)
Depth (m)
6/5/2007_Simulated
6/5/2007_Observed

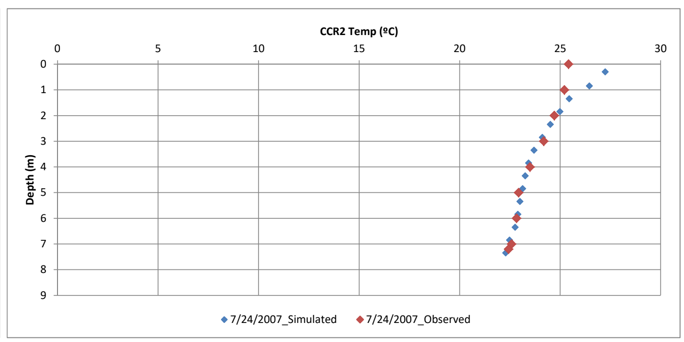

CCR3 Temp (ºC)
Depth (m)
6/19/2007_Simulated
6/19/2007_Observed

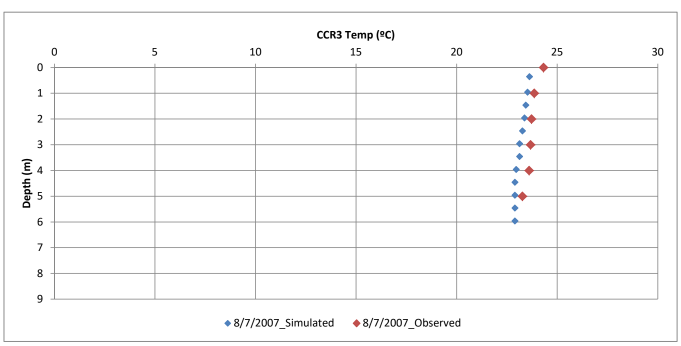

CCR2 Temp (ºC)
Depth (m)
6/19/2007_Simulated
6/19/2007_Observed

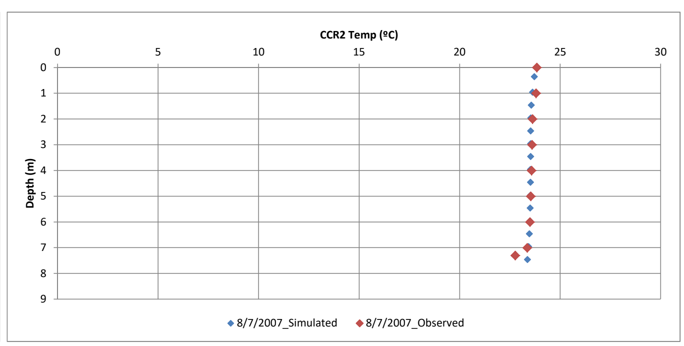

CCR3 Temp (ºC)
Depth (m)
7/10/2007_Simulated
7/10/2007_Observed

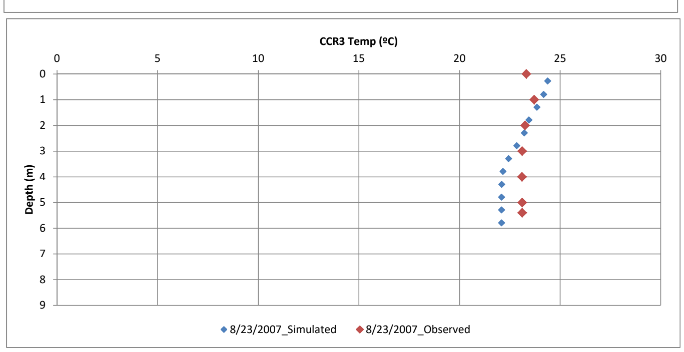

CCR2 Temp (ºC)
Depth (m)
7/10/2007_Simulated
7/10/2007_Observed

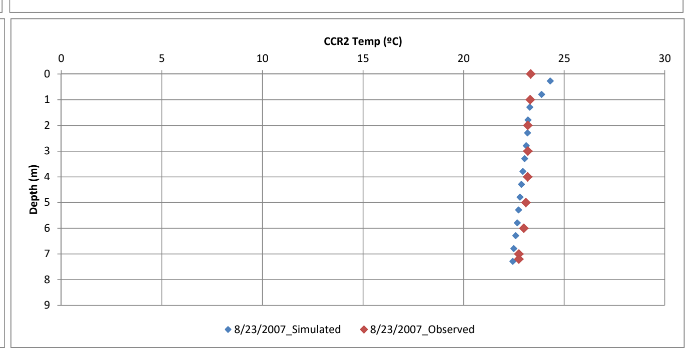

CCR3 Temp (ºC)
Depth (m)
7/24/2007_Simulated
7/24/2007_Observed

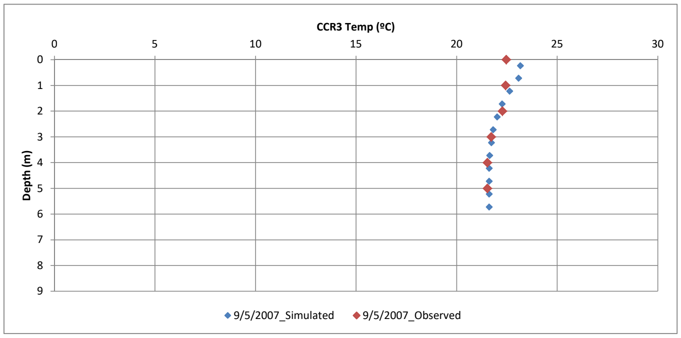

CCR2 Temp (ºC)
Depth (m)
7/24/2007_Simulated
7/24/2007_Observed

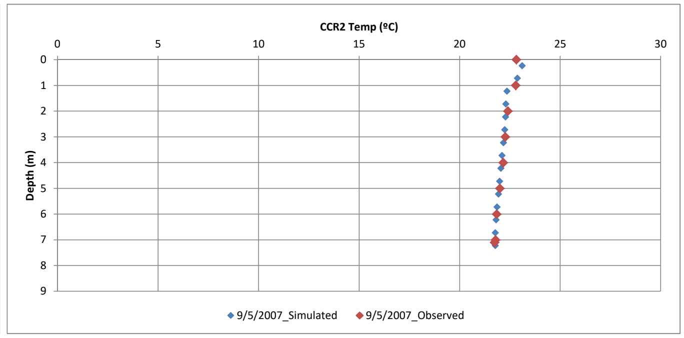

CCR3 Temp (ºC)
Depth (m)
8/7/2007_Simulated
8/7/2007_Observed

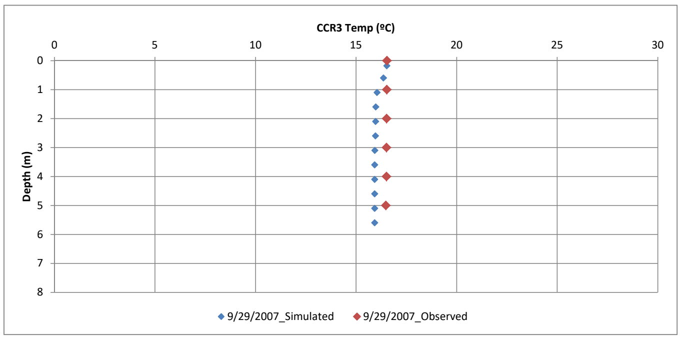

CCR2 Temp (ºC)
Depth (m)
8/7/2007_Simulated
8/7/2007_Observed

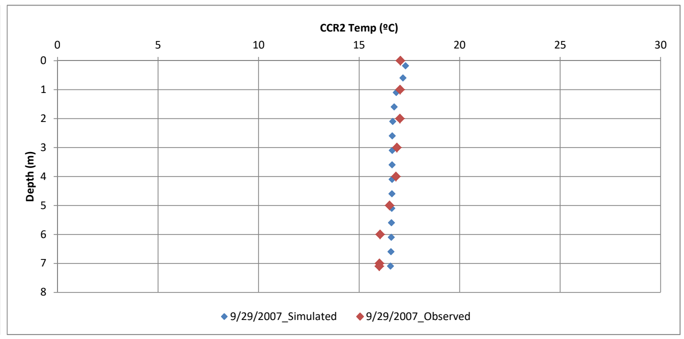

CCR3 Temp (ºC)
Depth (m)
8/23/2007_Simulated
8/23/2007_Observed

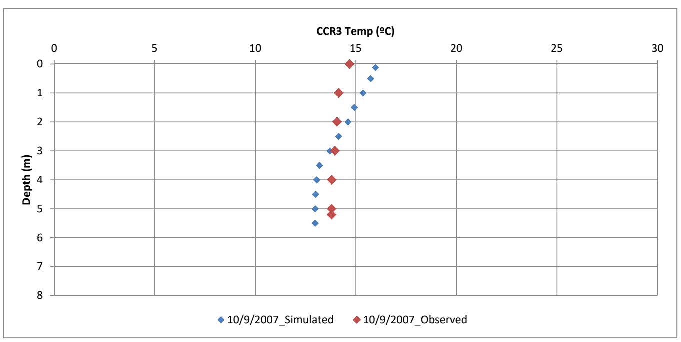

CCR2 Temp (ºC)
Depth (m)
8/23/2007_Simulated
8/23/2007_Observed


CCR3 Temp (ºC)
Depth (m)
9/5/2007_Simulated
9/5/2007_Observed


CCR2 Temp (ºC)
Depth (m)
9/5/2007_Simulated
9/5/2007_Observed


CCR3 Temp (ºC)
Depth (m)
9/29/2007_Simulated
9/29/2007_Observed


CCR2 Temp (ºC)
Depth (m)
9/29/2007_Simulated
9/29/2007_Observed


CCR3 Temp (ºC)
Depth (m)
10/9/2007_Simulated
10/9/2007_Observed

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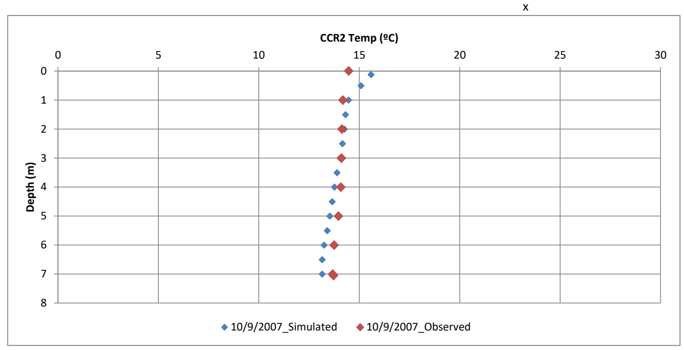
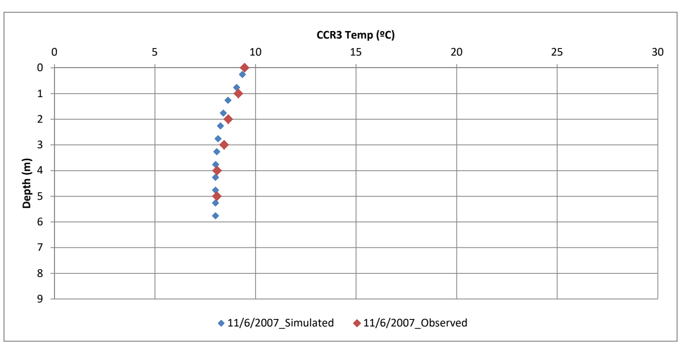
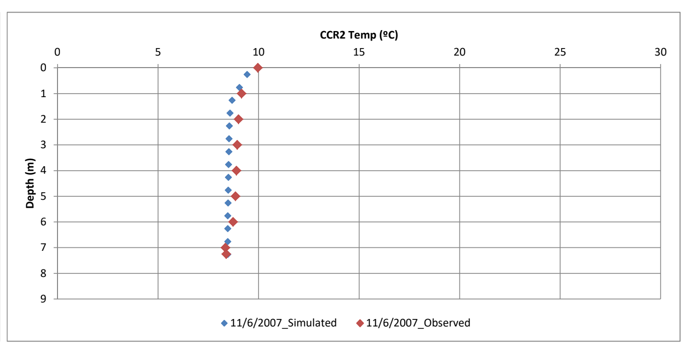
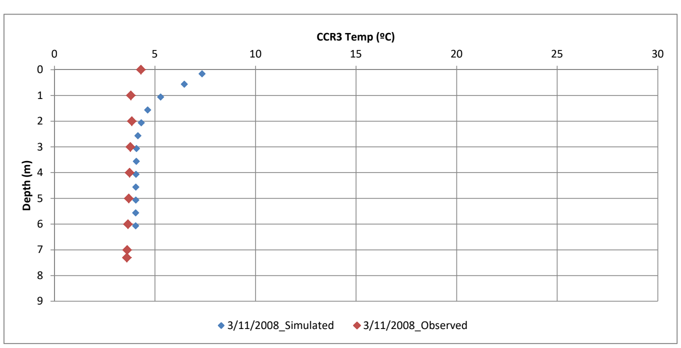
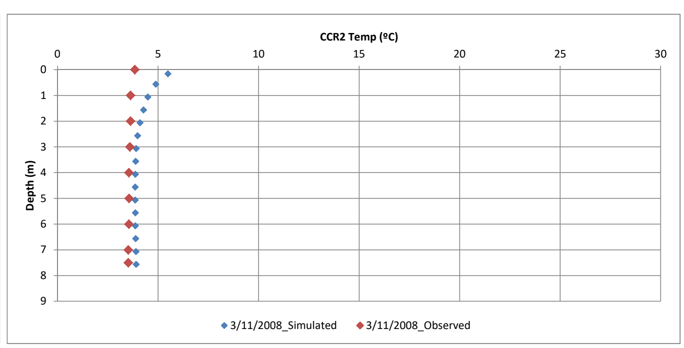
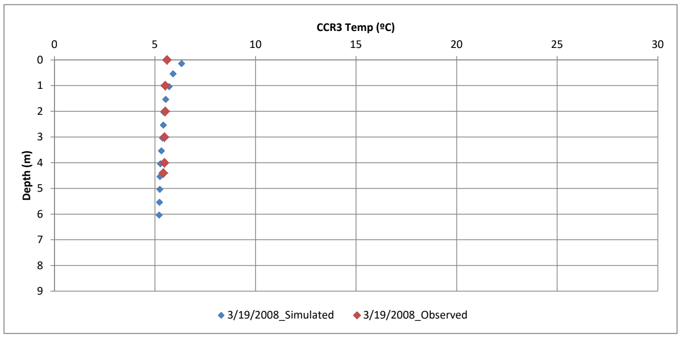

CCR2 Temp (ºC)
Depth (m)
10/9/2007_Simulated
10/9/2007_Observed

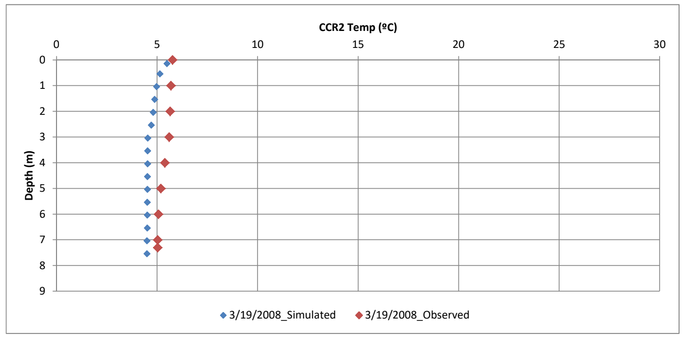

CCR3 Temp (ºC)
Depth (m)
11/6/2007_Simulated
11/6/2007_Observed

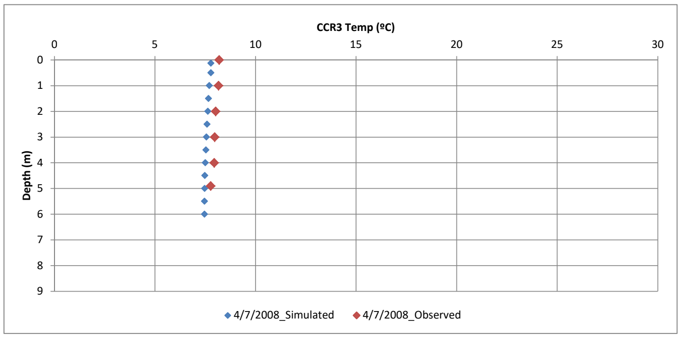

CCR2 Temp (ºC)
Depth (m)
11/6/2007_Simulated
11/6/2007_Observed

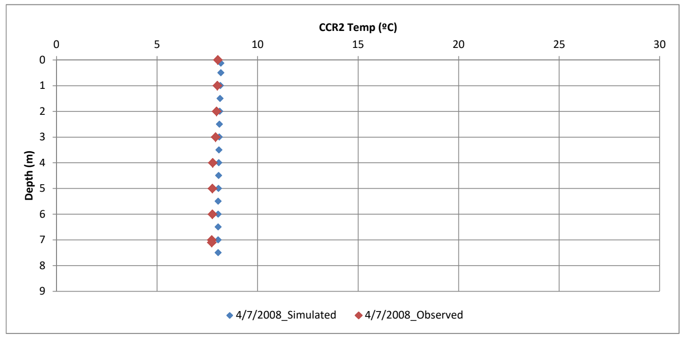

CCR3 Temp (ºC)
Depth (m)
3/11/2008_Simulated
3/11/2008_Observed

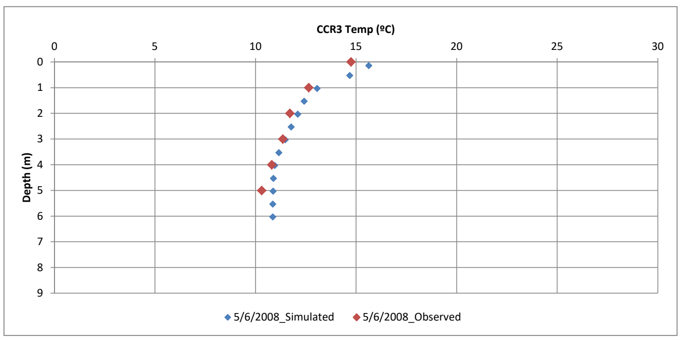

CCR2 Temp (ºC)
Depth (m)
3/11/2008_Simulated
3/11/2008_Observed

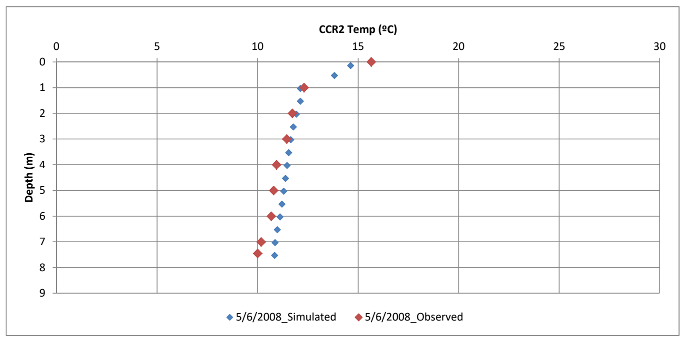

CCR3 Temp (ºC)
Depth (m)
3/19/2008_Simulated
3/19/2008_Observed

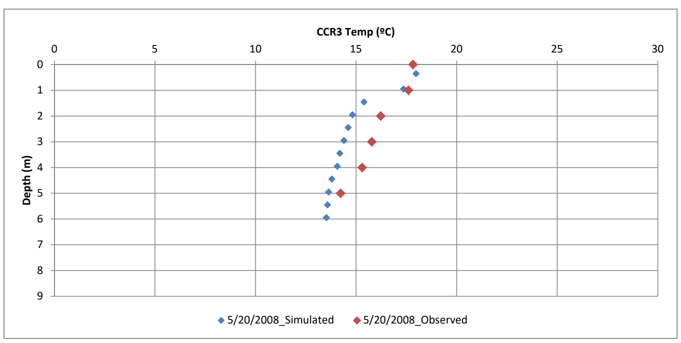

CCR2 Temp (ºC)
Depth (m)
3/19/2008_Simulated
3/19/2008_Observed

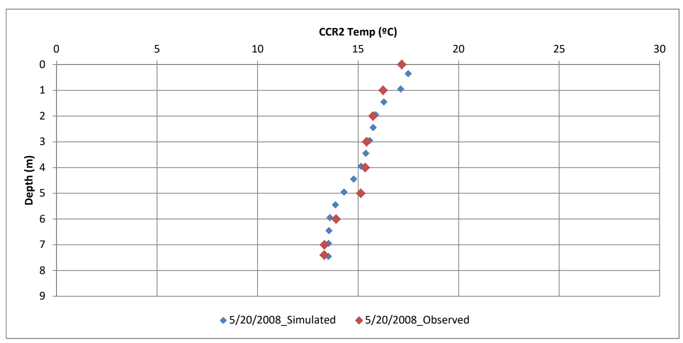

CCR3 Temp (ºC)
Depth (m)
4/7/2008_Simulated
4/7/2008_Observed


CCR2 Temp (ºC)
Depth (m)
4/7/2008_Simulated
4/7/2008_Observed


CCR3 Temp (ºC)
Depth (m)
5/6/2008_Simulated
5/6/2008_Observed


CCR2 Temp (ºC)
Depth (m)
5/6/2008_Simulated
5/6/2008_Observed


CCR3 Temp (ºC)
Depth (m)
5/20/2008_Simulated
5/20/2008_Observed


CCR2 Temp (ºC)
Depth (m)
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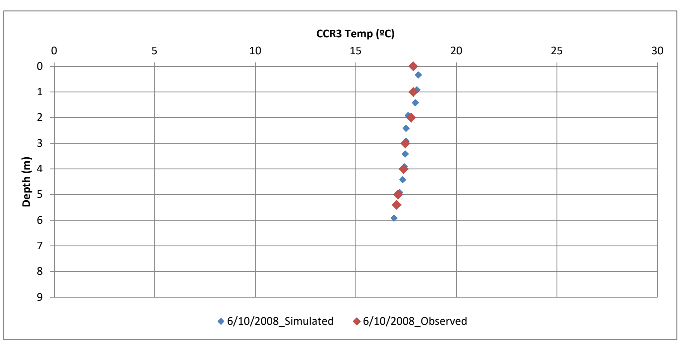
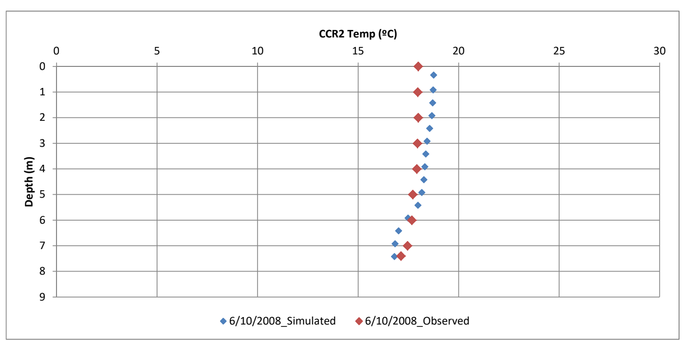
5/20/2008_Observed


CCR3 Temp (ºC)
Depth (m)
6/10/2008_Simulated
6/10/2008_Observed


CCR2 Temp (ºC)
Depth (m)
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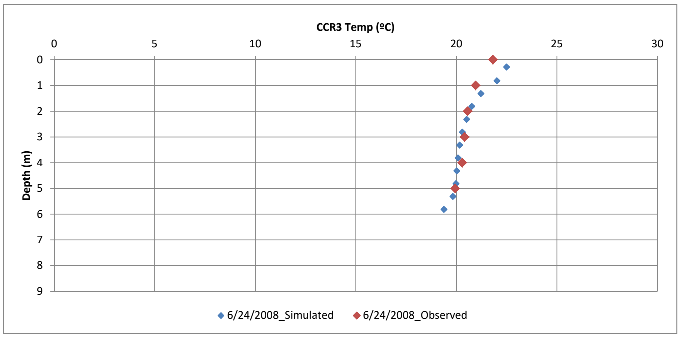
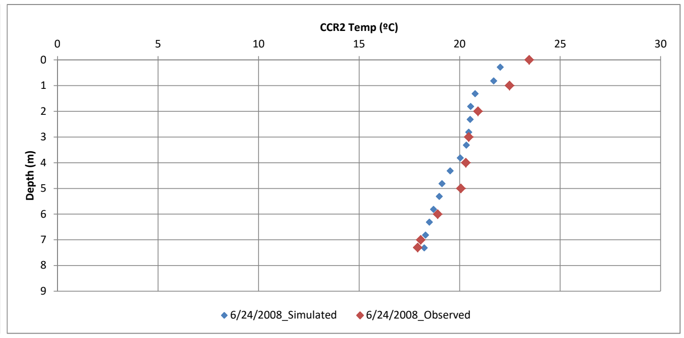
6/10/2008_Observed


CCR3 Temp (ºC)
Depth (m)
6/24/2008_Simulated
6/24/2008_Observed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Depth (m)
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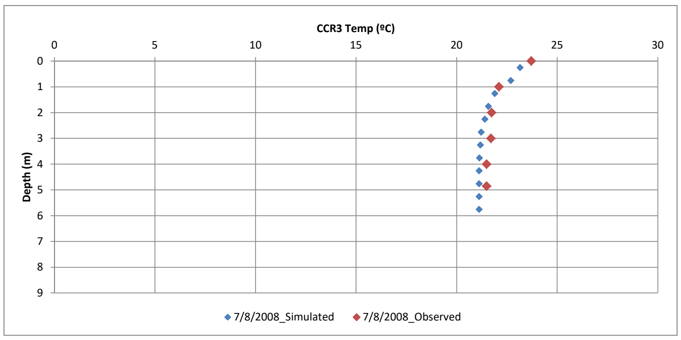
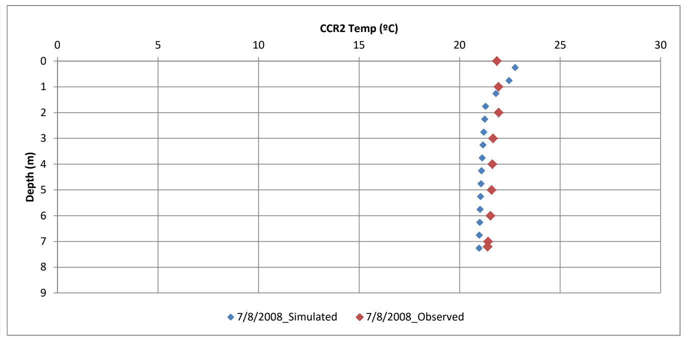
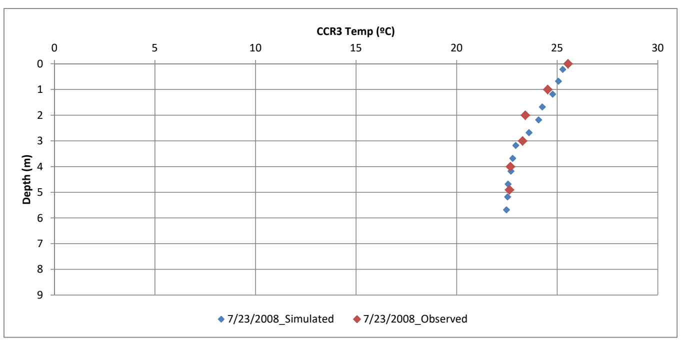
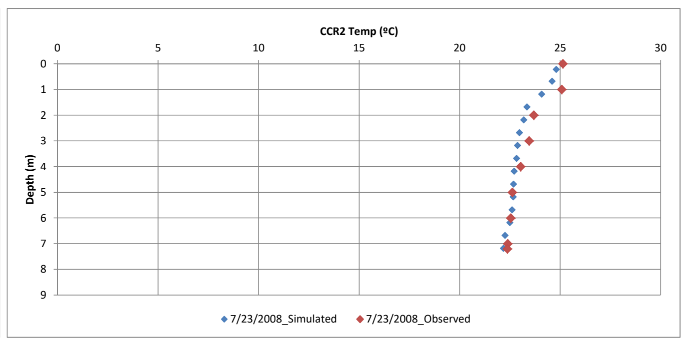
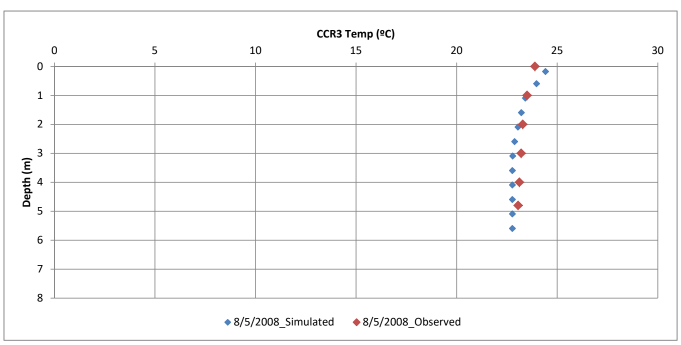
6/24/2008_Observed

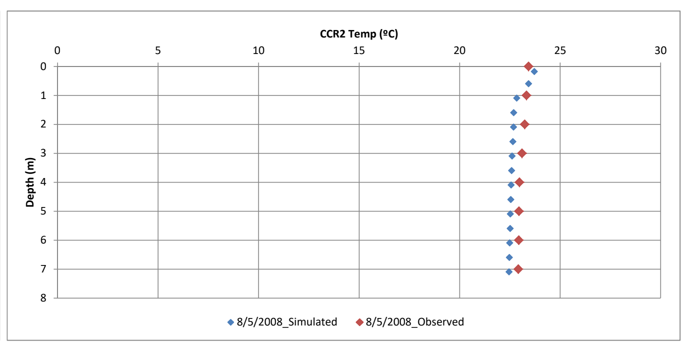

CCR3 Temp (ºC)
Depth (m)
7/8/2008_Simulated
7/8/2008_Observed

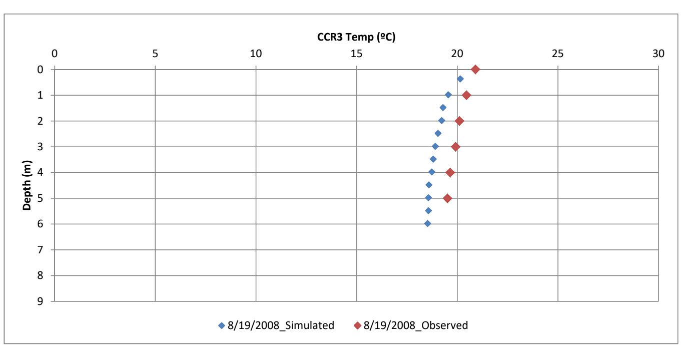

CCR2 Temp (ºC)
Depth (m)
7/8/2008_Simulated
7/8/2008_Observed

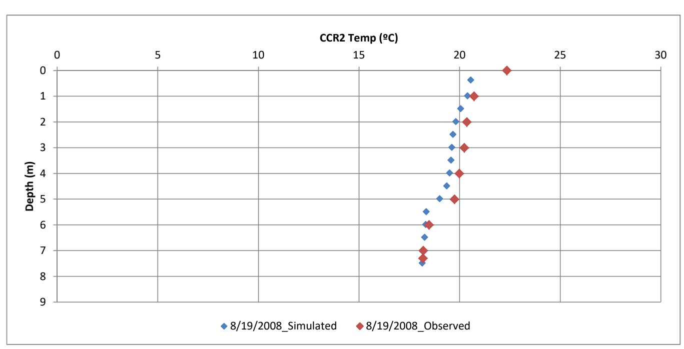

CCR3 Temp (ºC)
Depth (m)
7/23/2008_Simulated
7/23/2008_Observed

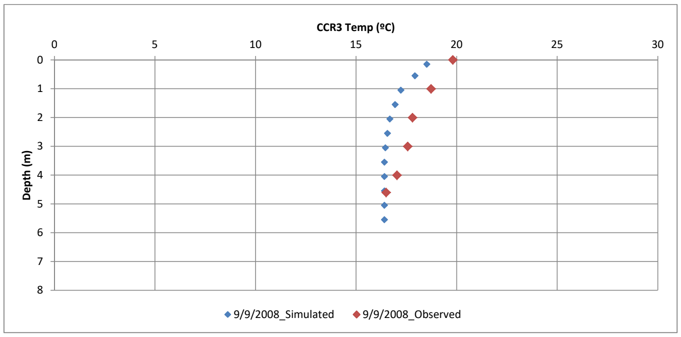

CCR2 Temp (ºC)
Depth (m)
7/23/2008_Simulated
7/23/2008_Observed

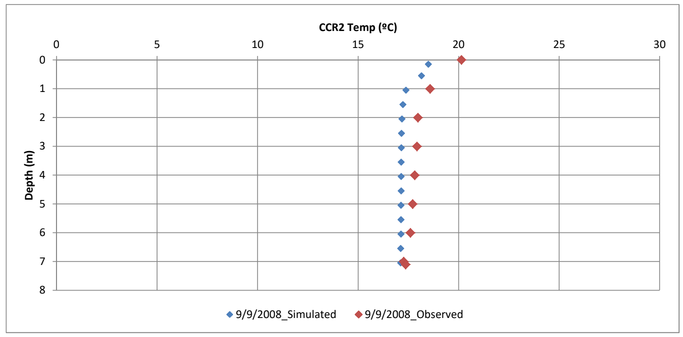

CCR3 Temp (ºC)
Depth (m)
8/5/2008_Simulated
8/5/2008_Observed


CCR2 Temp (ºC)
Depth (m)
8/5/2008_Simulated
8/5/2008_Observed


CCR3 Temp (ºC)
Depth (m)
8/19/2008_Simulated
8/19/2008_Observed


CCR2 Temp (ºC)
Depth (m)
8/19/2008_Simulated
8/19/2008_Observed


CCR3 Temp (ºC)
0 5 10 15 20 25 30
Depth (m)
0 1 2 3 4 5 6 7 8
9/9/2008_Simulated
9/9/2008_Observed


CCR2 Temp (ºC)
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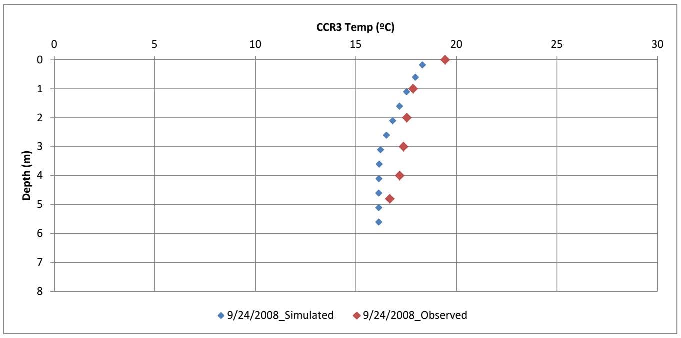
Depth (m)
0 1 2 3 4 5 6 7 8
9/9/2008_Simulated
9/9/2008_Observed


CCR3 Temp (ºC)
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Depth (m)
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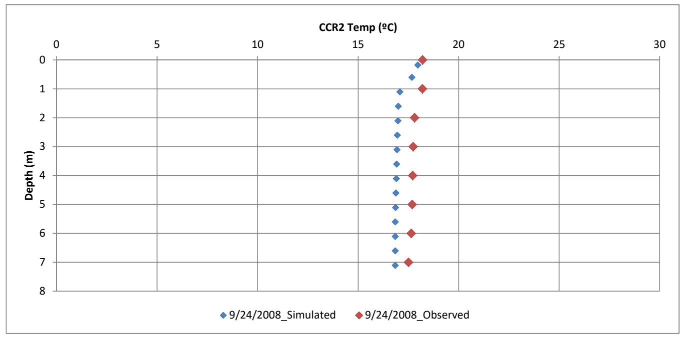
9/24/2008_Simulated
9/24/2008_Observed


CCR2 Temp (ºC)
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Depth (m)
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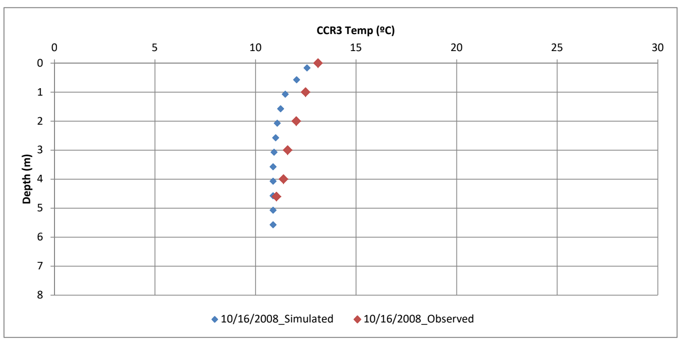
9/24/2008_Simulated
9/24/2008_Observed


CCR3 Temp (ºC)
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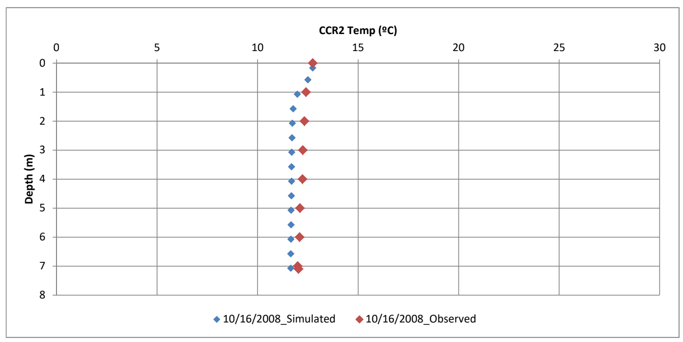
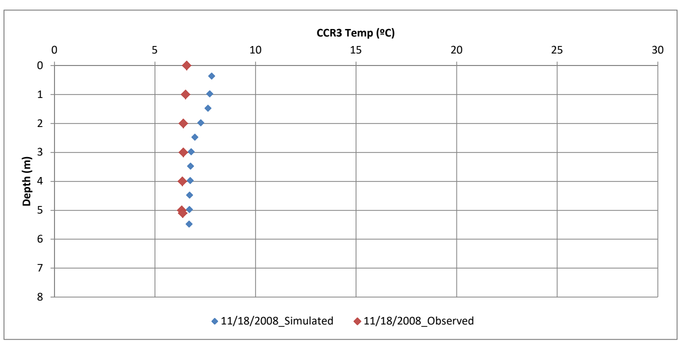
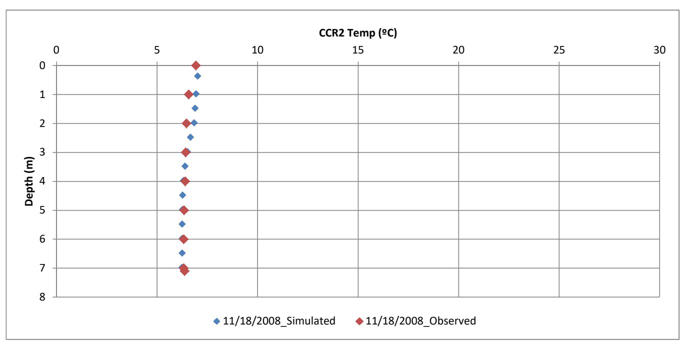
Depth (m)
0 1 2 3 4 5 6 7 8
10/16/2008_Simulated
10/16/2008_Observed


CCR2 Temp (ºC)
0 5 10 15 20 25 30
Depth (m)
0 1 2 3 4 5 6 7 8
10/16/2008_Simulated
10/16/2008_Observed


CCR3 Temp (ºC)
0 5 10 15 20 25 30
Depth (m)
0 1 2 3 4 5 6 7 8
11/18/2008_Simulated
11/18/2008_Observed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Depth (m)
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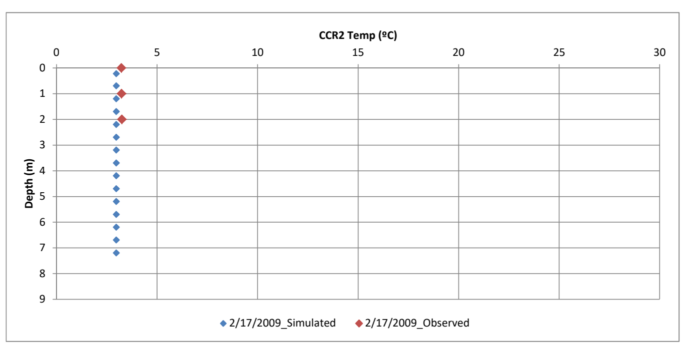
11/18/2008_Simulated
11/18/2008_Observed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Depth (m)
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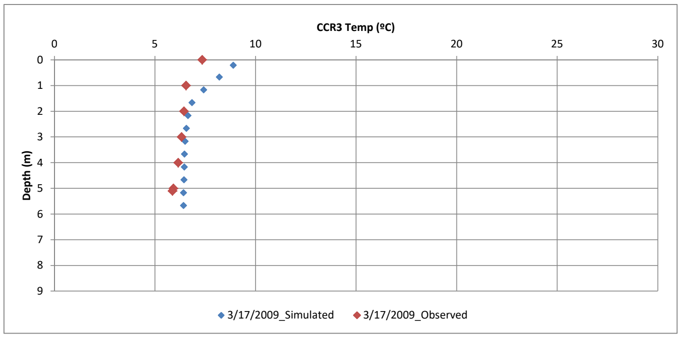
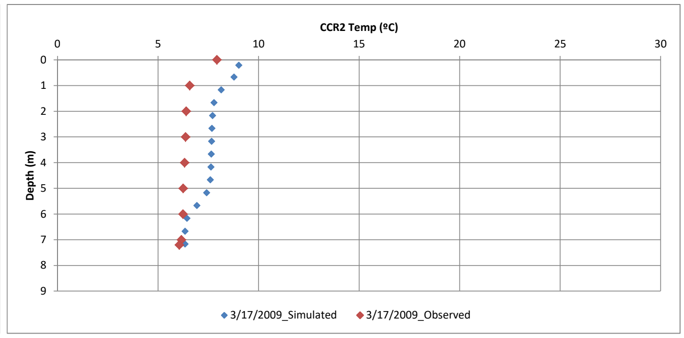
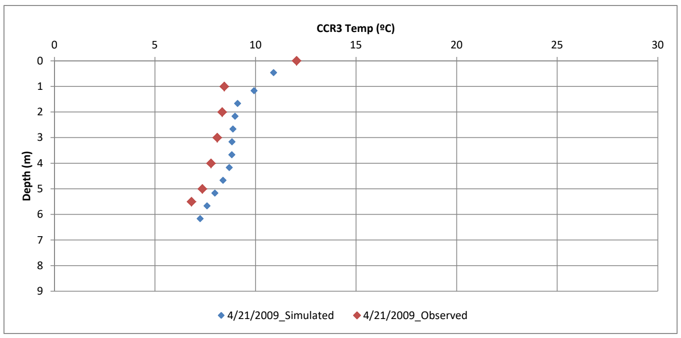
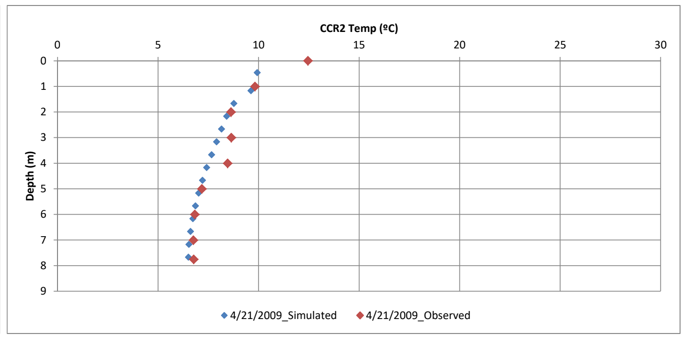
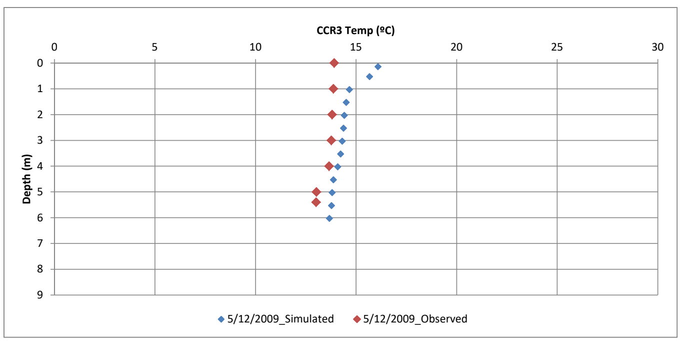
2/17/2009_Simulated
2/17/2009_Observed

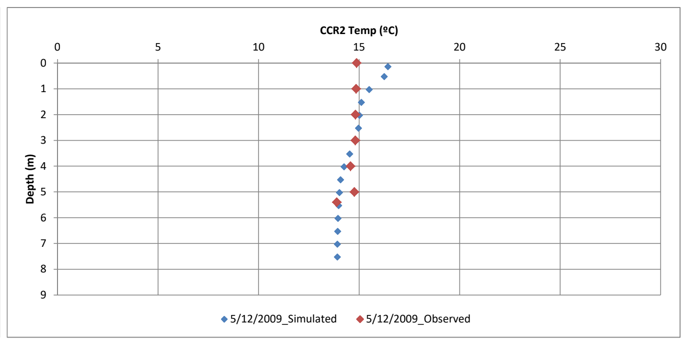

CCR3 Temp (ºC)
Depth (m)
3/17/2009_Simulated
3/17/2009_Observed


CCR2 Temp (ºC)
Depth (m)
3/17/2009_Simulated
3/17/2009_Observed


CCR3 Temp (ºC)
Depth (m)
4/21/2009_Simulated
4/21/2009_Observed


CCR2 Temp (ºC)
Depth (m)
4/21/2009_Simulated
4/21/2009_Observed


CCR3 Temp (ºC)
Depth (m)
5/12/2009_Simulated
5/12/2009_Observed


CCR2 Temp (ºC)
Depth (m)
5/12/2009_Simulated
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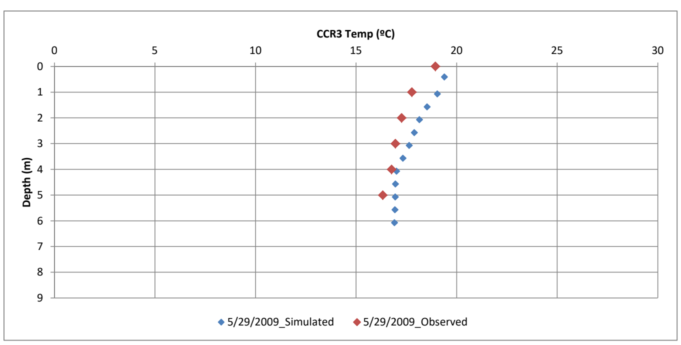
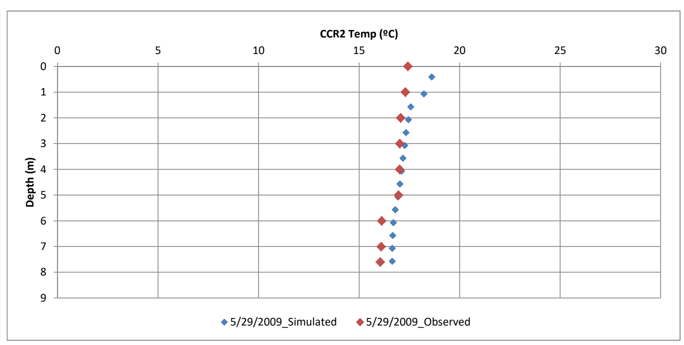
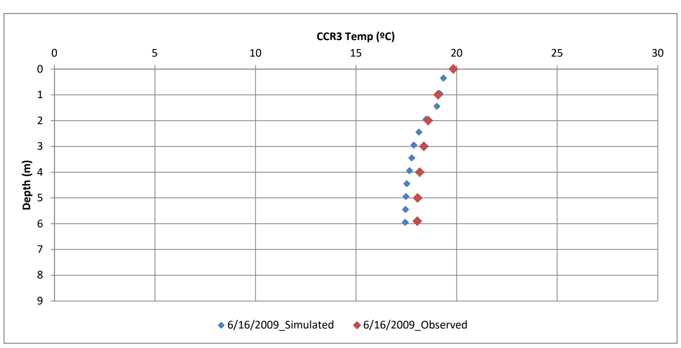
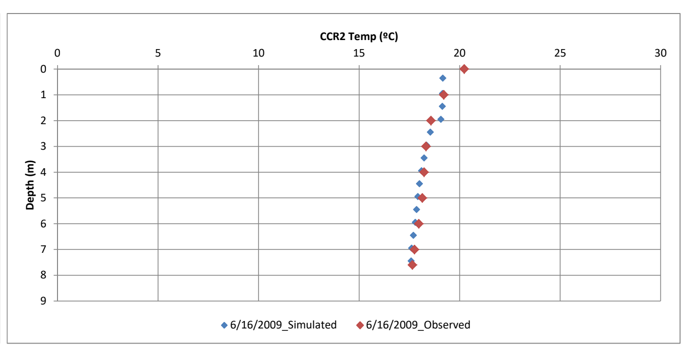
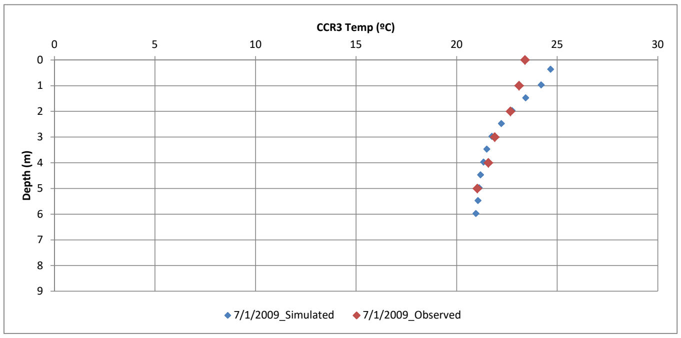
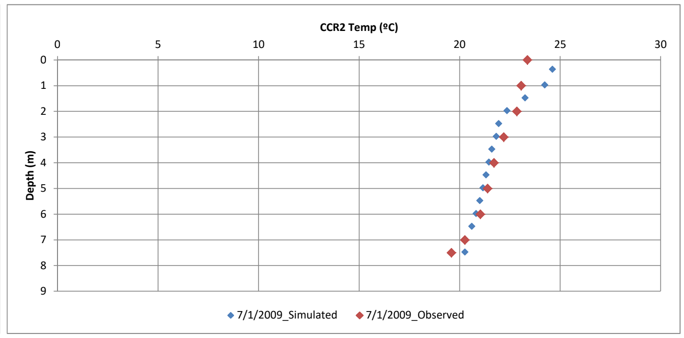

CCR3 Temp (ºC)
Depth (m)
5/29/2009_Simulated
5/29/2009_Observed


CCR2 Temp (ºC)
Depth (m)
5/29/2009_Simulated
5/29/2009_Observed

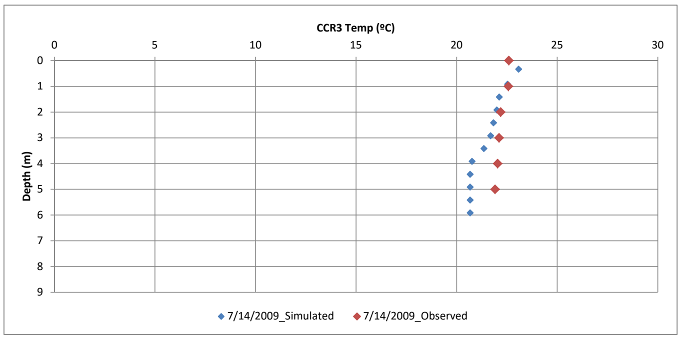

CCR3 Temp (ºC)
Depth (m)
6/16/2009_Simulated
6/16/2009_Observed

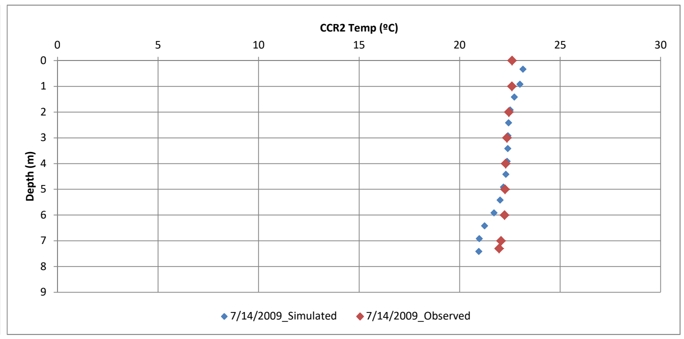

CCR2 Temp (ºC)
Depth (m)
6/16/2009_Simulated
6/16/2009_Observed

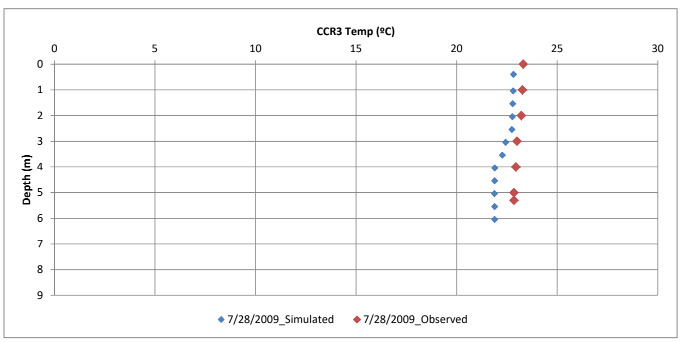

CCR3 Temp (ºC)
Depth (m)
7/1/2009_Simulated
7/1/2009_Observed

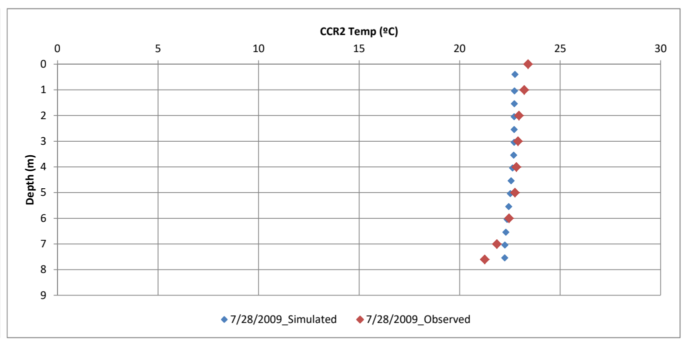

CCR2 Temp (ºC)
Depth (m)
7/1/2009_Simulated
7/1/2009_Observed

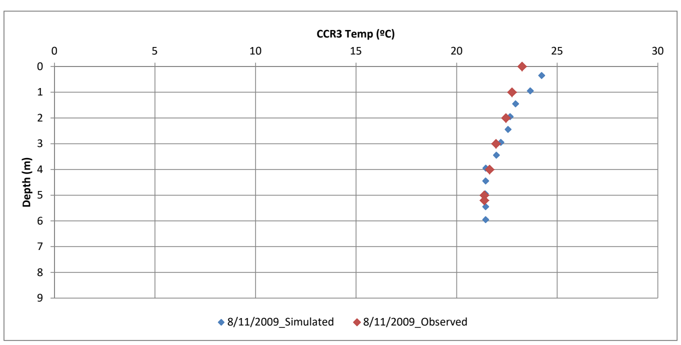
x

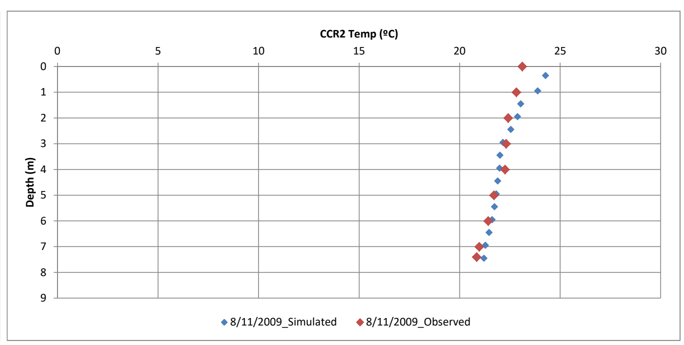

CCR3 Temp (ºC)
Depth (m)
7/14/2009_Simulated
7/14/2009_Observed

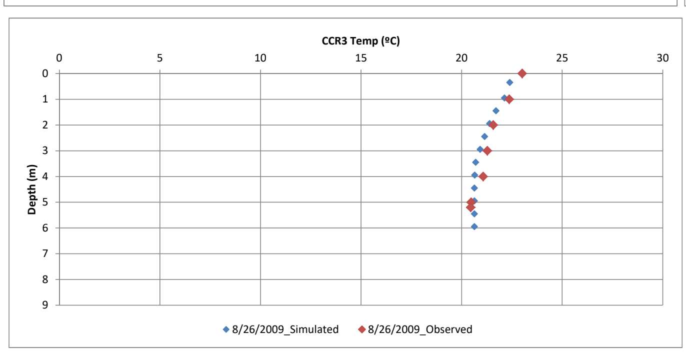

CCR2 Temp (ºC)
Depth (m)
7/14/2009_Simulated
7/14/2009_Observed

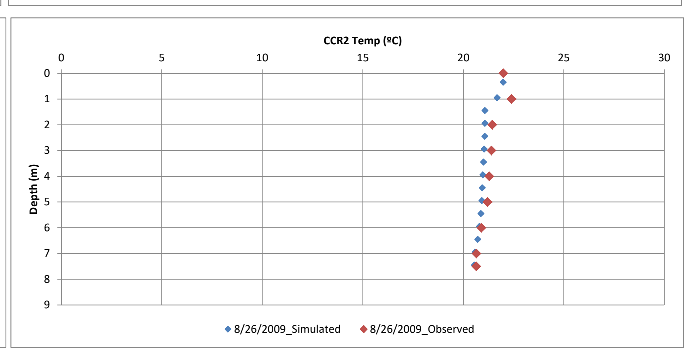

CCR3 Temp (ºC)
Depth (m)
7/28/2009_Simulated
7/28/2009_Observed

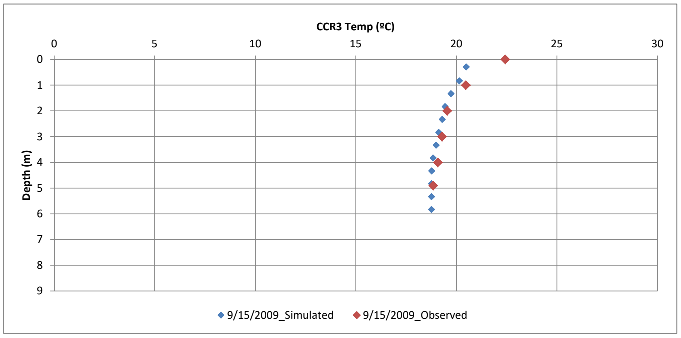

CCR2 Temp (ºC)
Depth (m)
7/28/2009_Simulated
7/28/2009_Observed

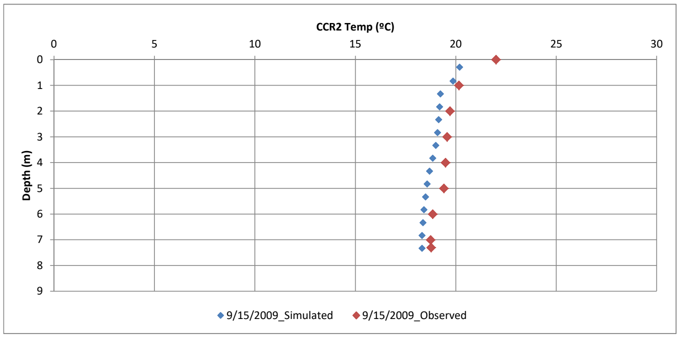

CCR3 Temp (ºC)
Depth (m)
8/11/2009_Simulated
8/11/2009_Observed

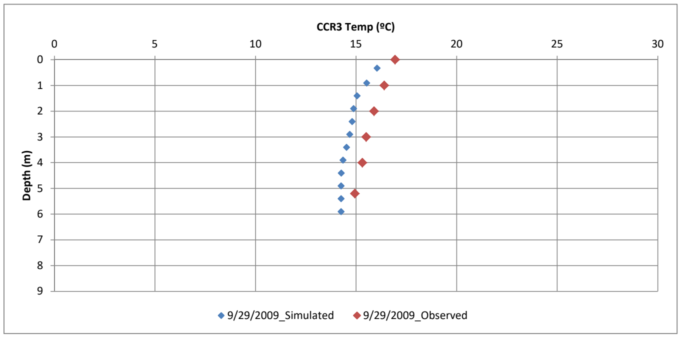

CCR2 Temp (ºC)
Depth (m)
8/11/2009_Simulated
8/11/2009_Observed

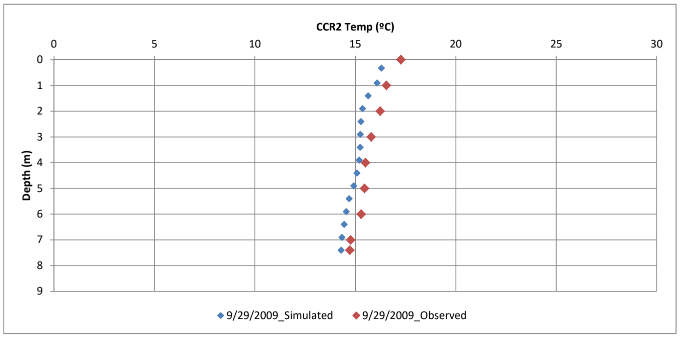

CCR3 Temp (ºC)
Depth (m)
8/26/2009_Simulated
8/26/2009_Observed

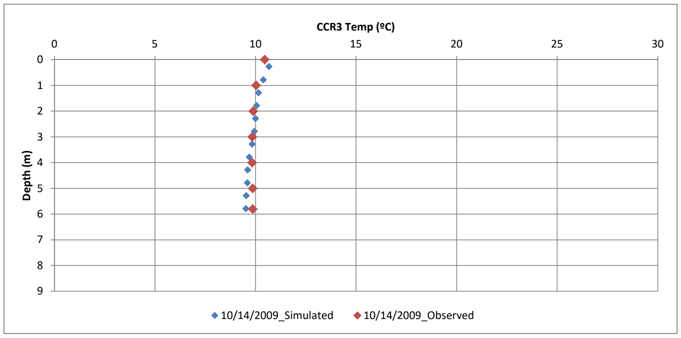

CCR2 Temp (ºC)
Depth (m)
8/26/2009_Simulated
8/26/2009_Observed

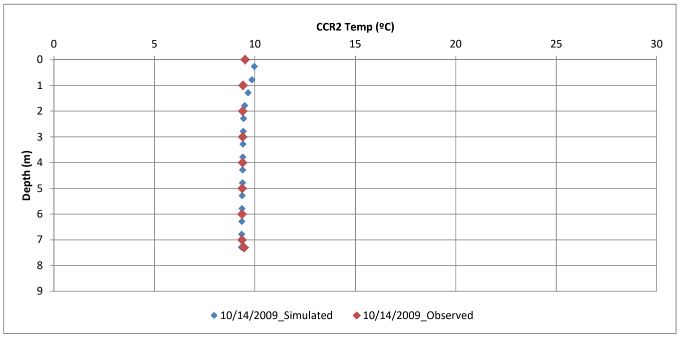

CCR3 Temp (ºC)
Depth (m)
9/15/2009_Simulated
9/15/2009_Observed

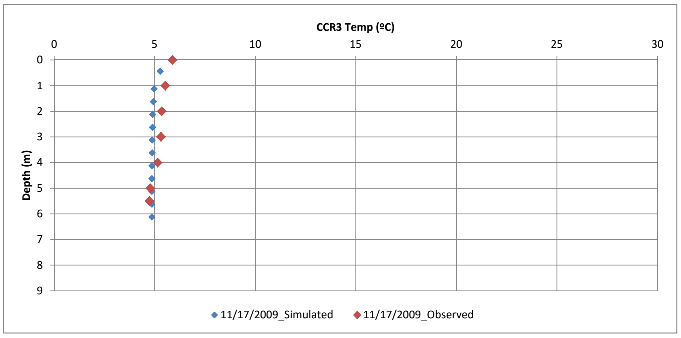

CCR2 Temp (ºC)
Depth (m)
9/15/2009_Simulated
9/15/2009_Observed

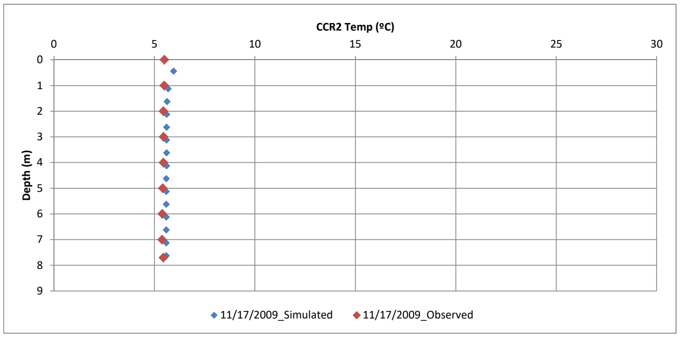

CCR3 Temp (ºC)
Depth (m)
9/29/2009_Simulated
9/29/2009_Observed

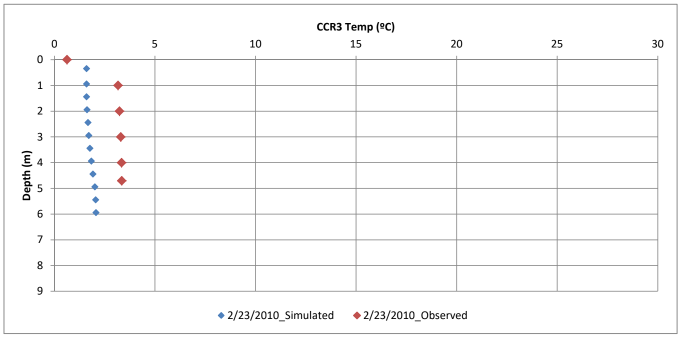

CCR2 Temp (ºC)
Depth (m)
9/29/2009_Simulated
9/29/2009_Observed

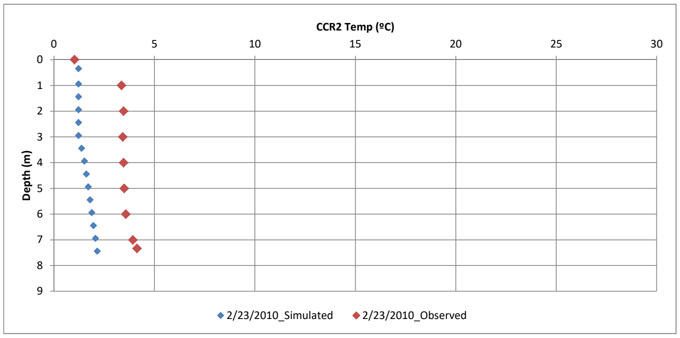

CCR3 Temp (ºC)
Depth (m)
10/14/2009_Simulated
10/14/2009_Observed

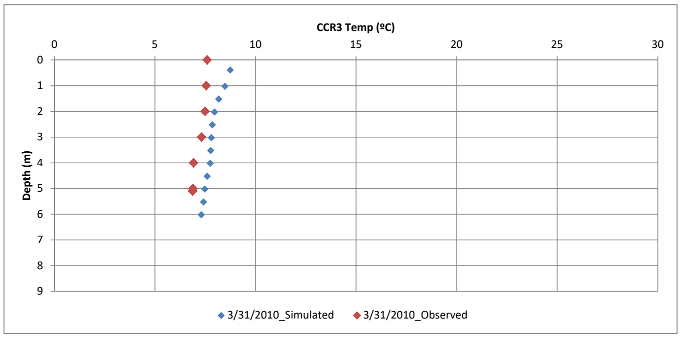

CCR2 Temp (ºC)
Depth (m)
10/14/2009_Simulated
10/14/2009_Observed

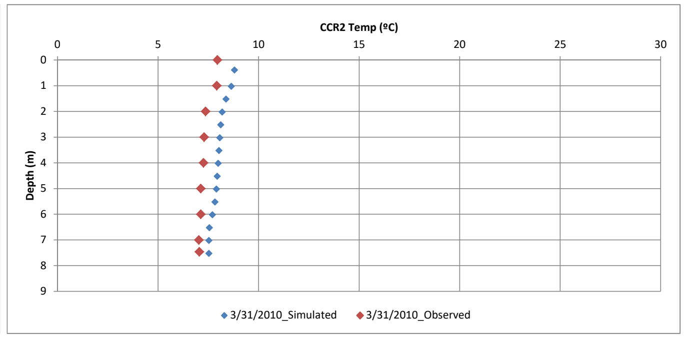

CCR3 Temp (ºC)
Depth (m)
11/17/2009_Simulated
11/17/2009_Observed

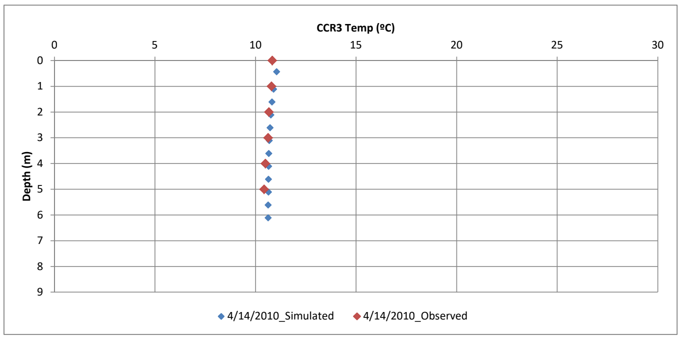

CCR2 Temp (ºC)
Depth (m)
11/17/2009_Simulated
11/17/2009_Observed

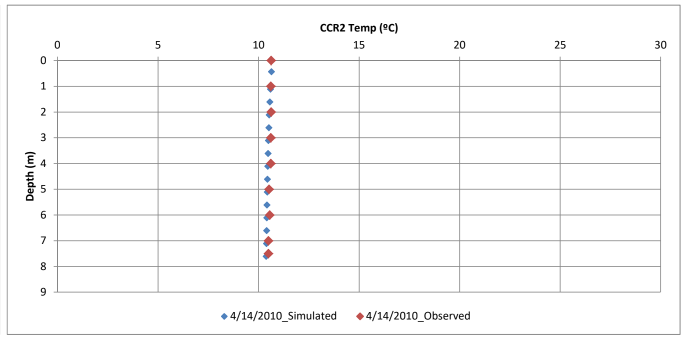

CCR3 Temp (ºC)
Depth (m)
2/23/2010_Simulated
2/23/2010_Observed

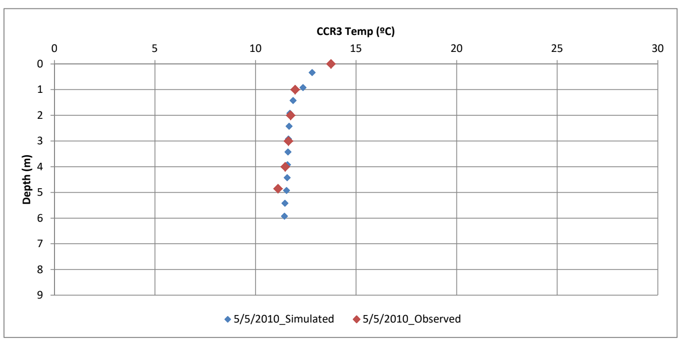

CCR2 Temp (ºC)
Depth (m)
2/23/2010_Simulated
2/23/2010_Observed

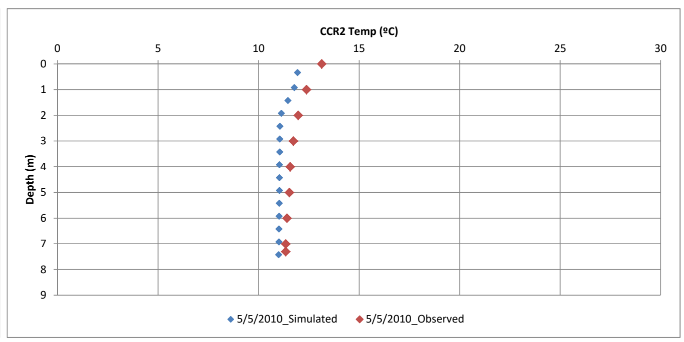

CCR3 Temp (ºC)
Depth (m)
3/31/2010_Simulated
3/31/2010_Observed

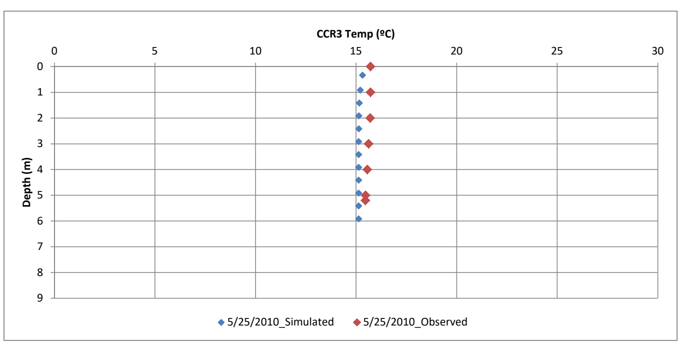

CCR2 Temp (ºC)
Depth (m)
3/31/2010_Simulated
3/31/2010_Observed

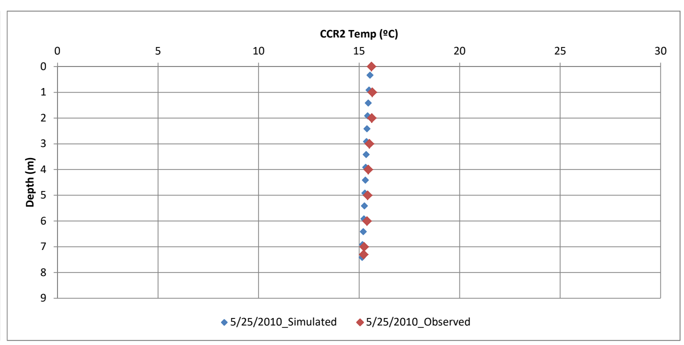

CCR3 Temp (ºC)
Depth (m)
4/14/2010_Simulated
4/14/2010_Observed

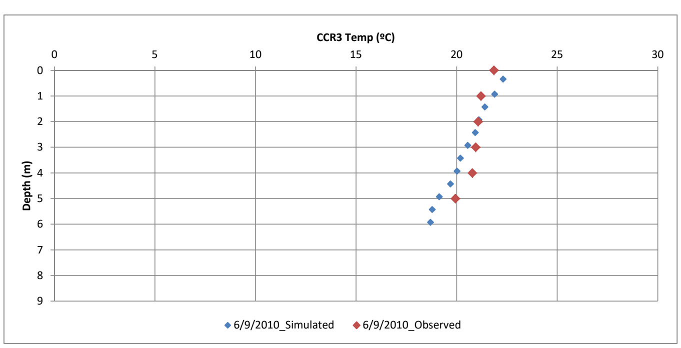

CCR2 Temp (ºC)
Depth (m)
4/14/2010_Simulated
4/14/2010_Observed

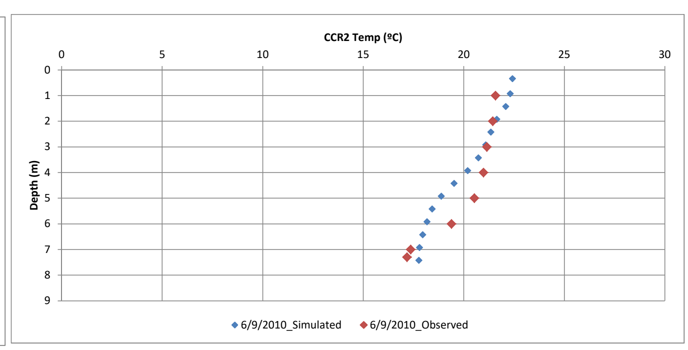

CCR3 Temp (ºC)
Depth (m)
5/5/2010_Simulated
5/5/2010_Observed

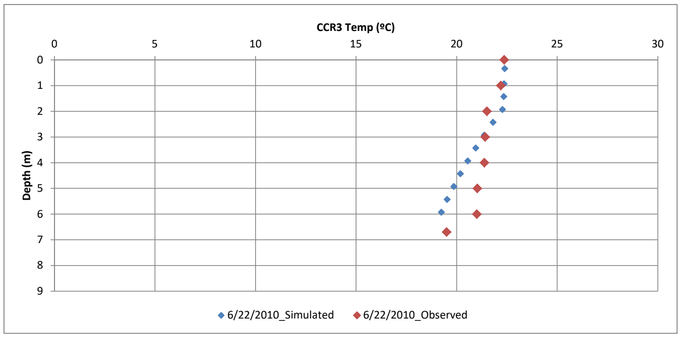

CCR2 Temp (ºC)
Depth (m)
5/5/2010_Simulated
5/5/2010_Observed

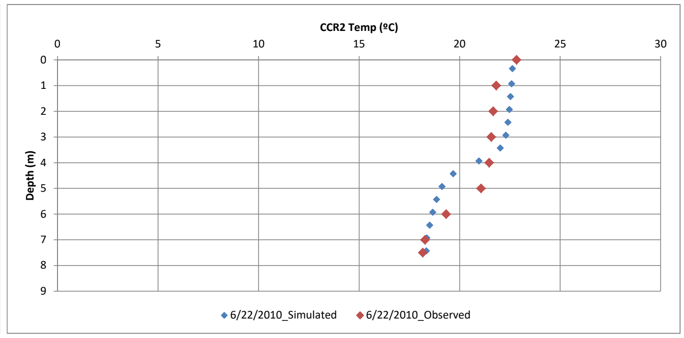

CCR3 Temp (ºC)
Depth (m)
5/25/2010_Simulated
5/25/2010_Observed

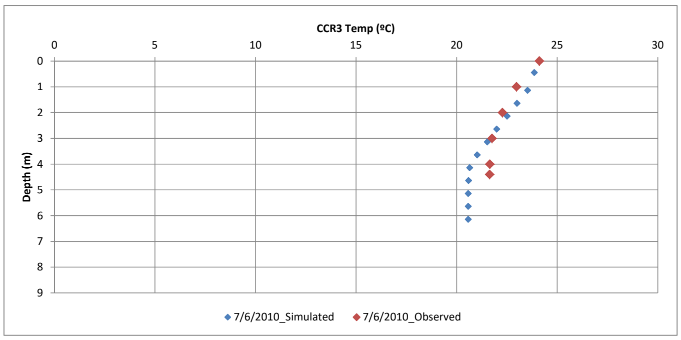

CCR2 Temp (ºC)
Depth (m)
5/25/2010_Simulated
5/25/2010_Observed

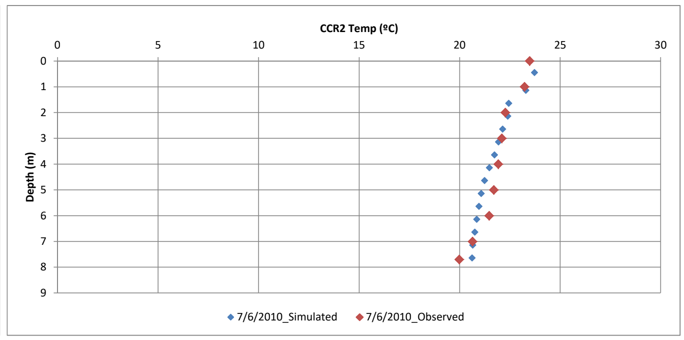

CCR3 Temp (ºC)
Depth (m)
6/9/2010_Simulated
6/9/2010_Observed

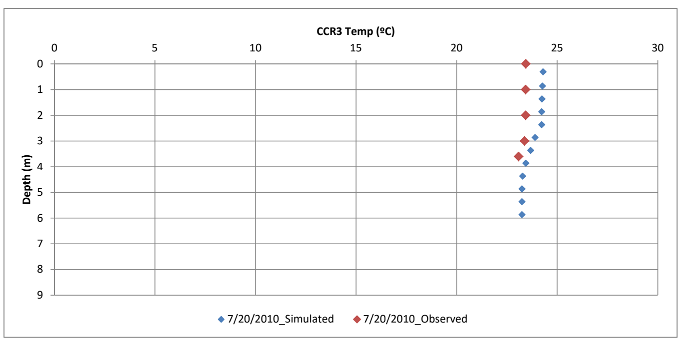

CCR2 Temp (ºC)
Depth (m)
6/9/2010_Simulated
6/9/2010_Observed

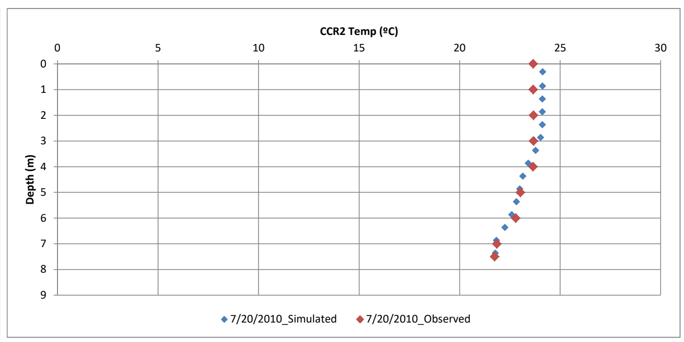

CCR3 Temp (ºC)
Depth (m)
6/22/2010_Simulated
6/22/2010_Observed

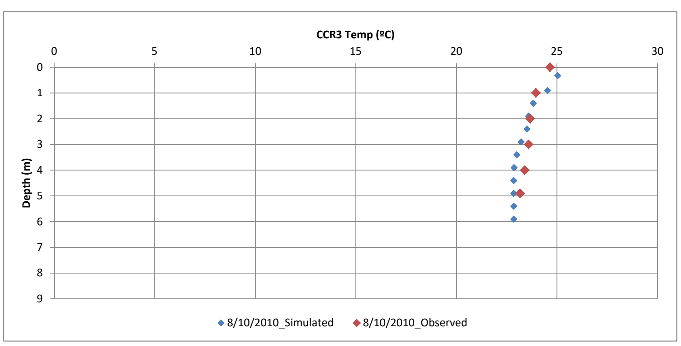

CCR2 Temp (ºC)
Depth (m)
6/22/2010_Simulated
6/22/2010_Observed

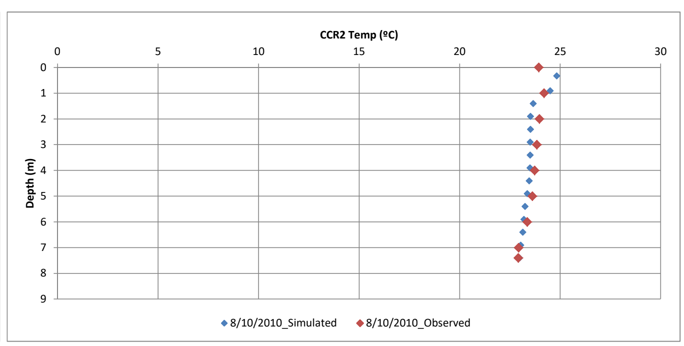

CCR3 Temp (ºC)
Depth (m)
7/6/2010_Simulated
7/6/2010_Observed

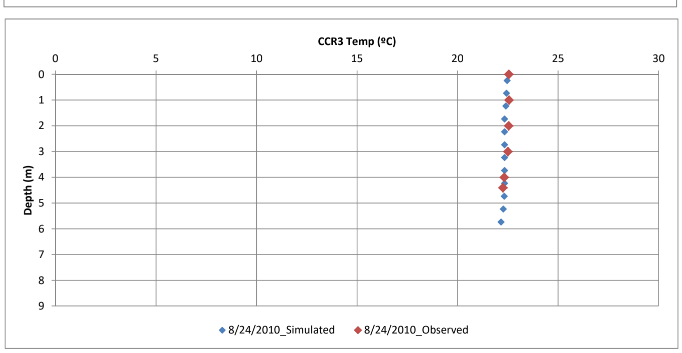

CCR2 Temp (ºC)
Depth (m)
7/6/2010_Simulated
7/6/2010_Observed

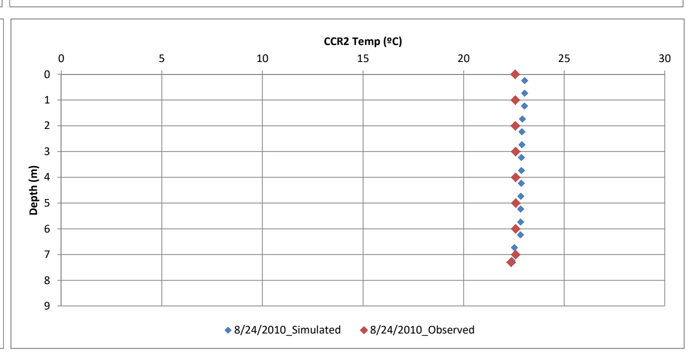

CCR3 Temp (ºC)
Depth (m)
7/20/2010_Simulated
7/20/2010_Observed

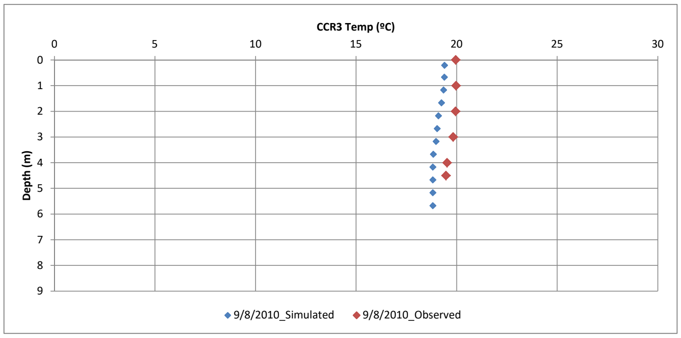

CCR2 Temp (ºC)
Depth (m)
7/20/2010_Simulated
7/20/2010_Observed

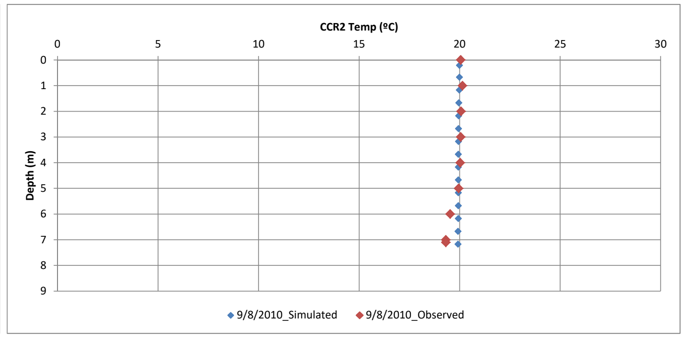

CCR3 Temp (ºC)
Depth (m)
8/10/2010_Simulated
8/10/2010_Observed

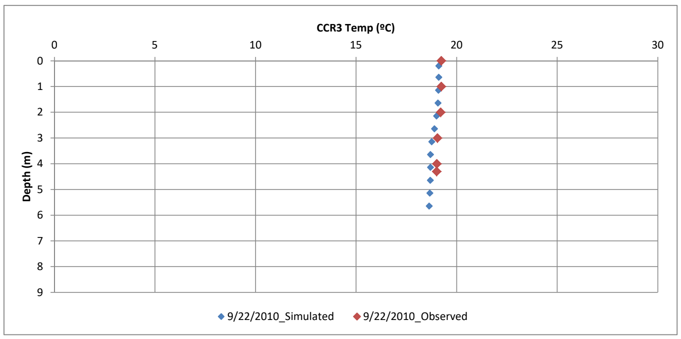

CCR2 Temp (ºC)
Depth (m)
8/10/2010_Simulated
8/10/2010_Observed

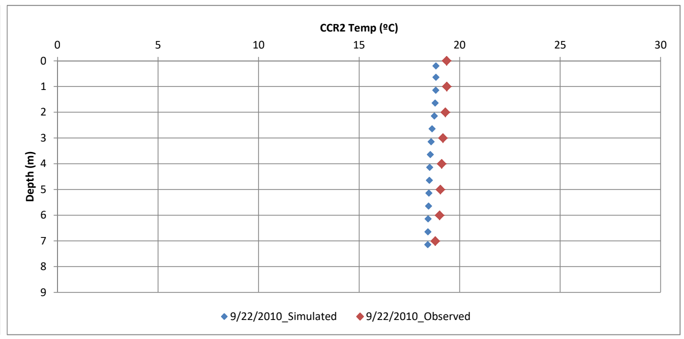

CCR3 Temp (ºC)
Depth (m)
8/24/2010_Simulated
8/24/2010_Observed

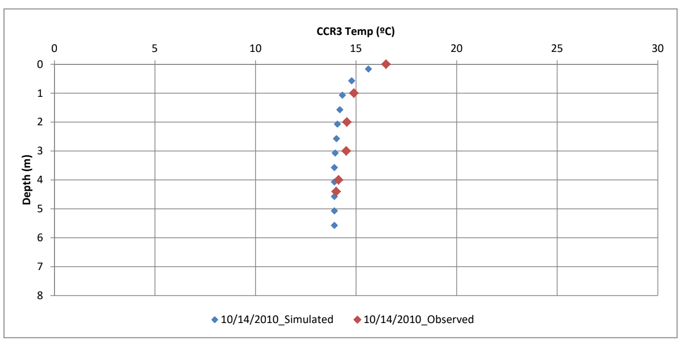

CCR2 Temp (ºC)
Depth (m)
8/24/2010_Simulated
8/24/2010_Observed

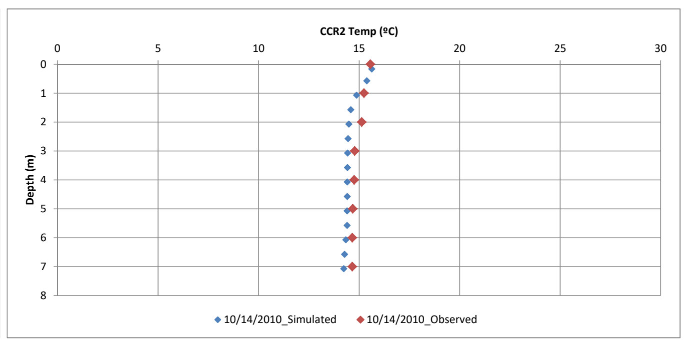

CCR3 Temp (ºC)
Depth (m)
9/8/2010_Simulated
9/8/2010_Observed

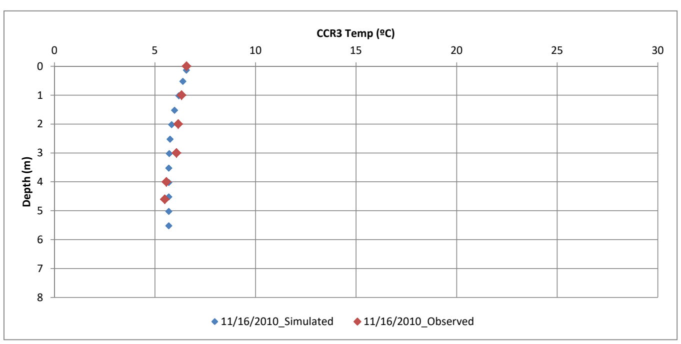

CCR2 Temp (ºC)
Depth (m)
9/8/2010_Simulated
9/8/2010_Observed

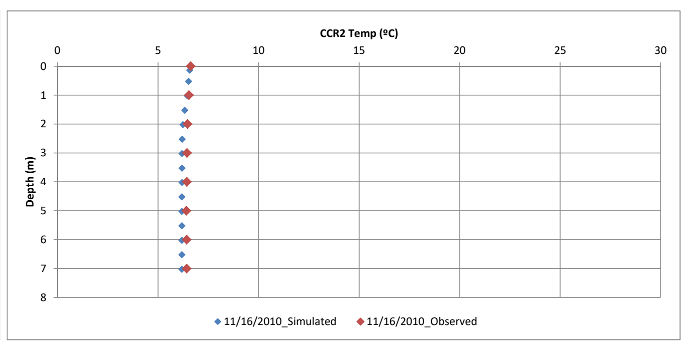

CCR3 Temp (ºC)
Depth (m)
9/22/2010_Simulated
9/22/2010_Observed

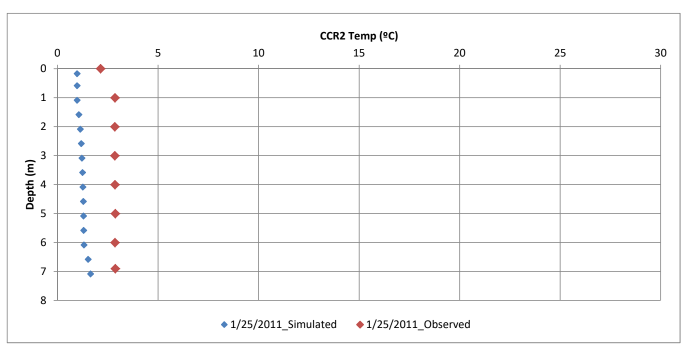

CCR2 Temp (ºC)
Depth (m)
9/22/2010_Simulated
9/22/2010_Observed


CCR3 Temp (ºC)
Depth (m)
10/14/2010_Simulated
10/14/2010_Observed

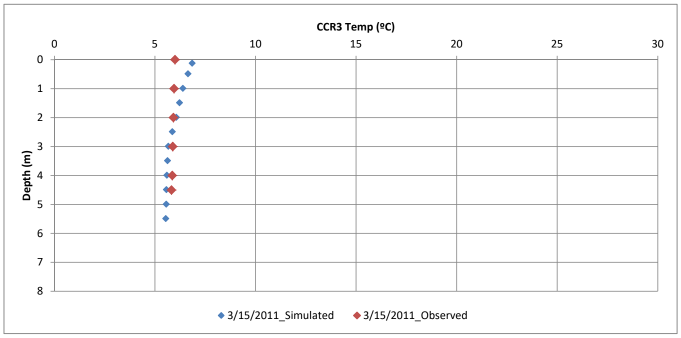

CCR2 Temp (ºC)
Depth (m)
10/14/2010_Simulated
10/14/2010_Observed

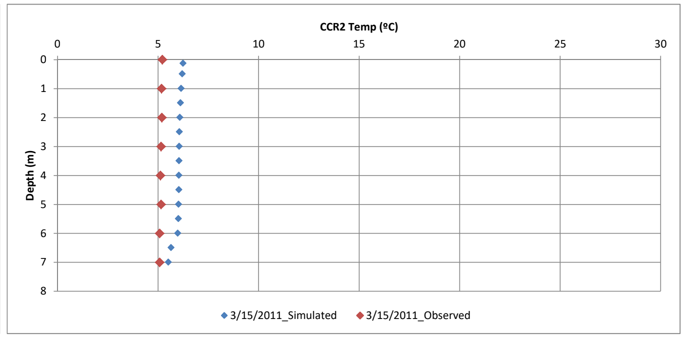

CCR3 Temp (ºC)
Depth (m)
11/16/2010_Simulated
11/16/2010_Observed

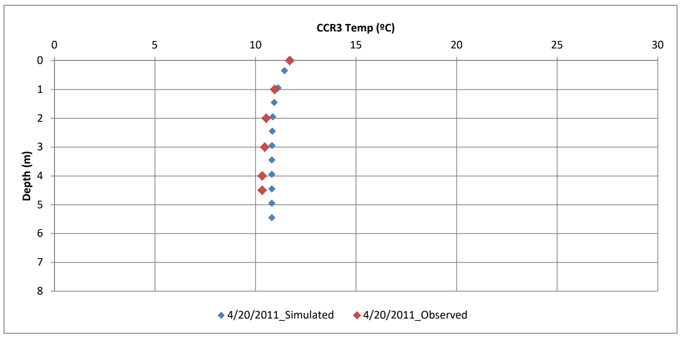

CCR2 Temp (ºC)
Depth (m)
11/16/2010_Simulated
11/16/2010_Observed

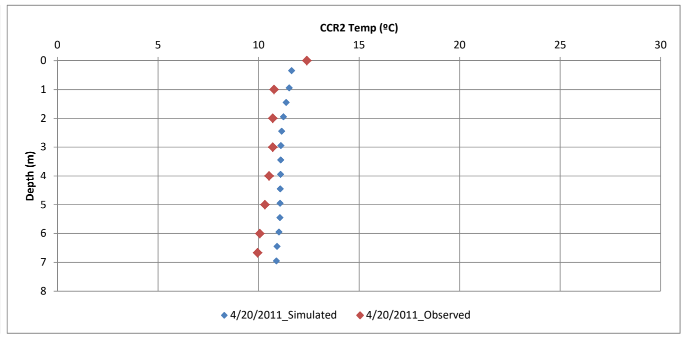

CCR2 Temp (ºC)
Depth (m)
1/25/2011_Simulated
1/25/2011_Observed

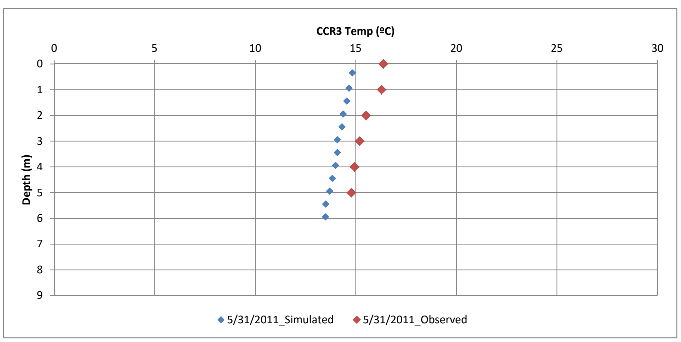
x

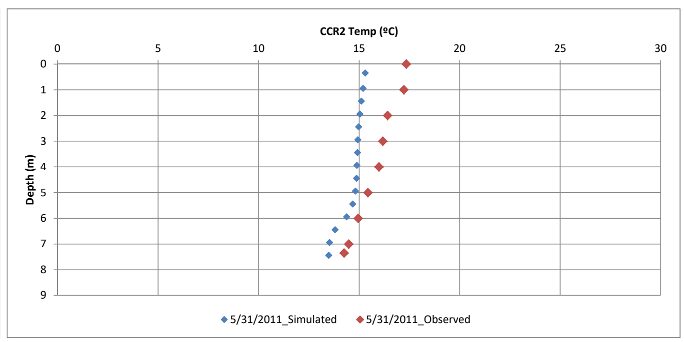

CCR3 Temp (ºC)
Depth (m)
3/15/2011_Simulated
3/15/2011_Observed

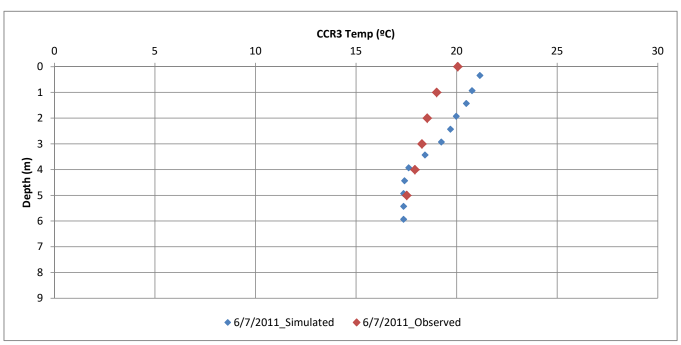

CCR2 Temp (ºC)
Depth (m)
3/15/2011_Simulated
3/15/2011_Observed

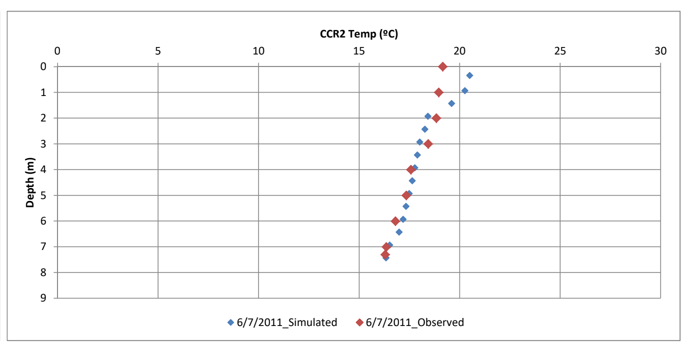

CCR3 Temp (ºC)
Depth (m)
4/20/2011_Simulated
4/20/2011_Observed

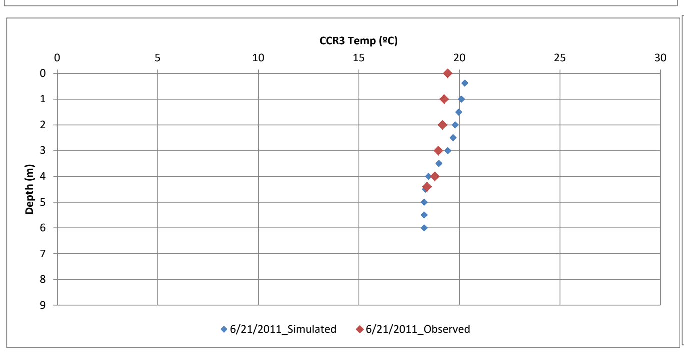

CCR2 Temp (ºC)
Depth (m)
4/20/2011_Simulated
4/20/2011_Observed

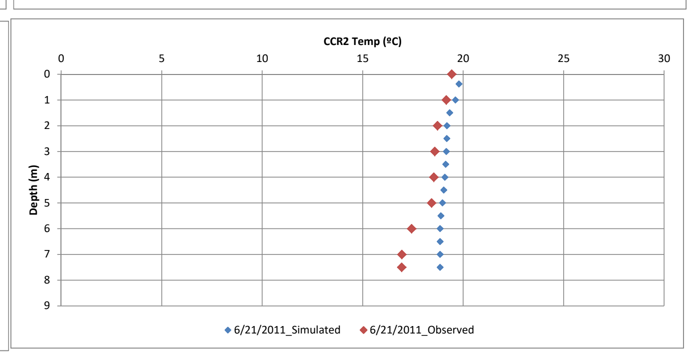

CCR3 Temp (ºC)
Depth (m)
5/31/2011_Simulated
5/31/2011_Observed

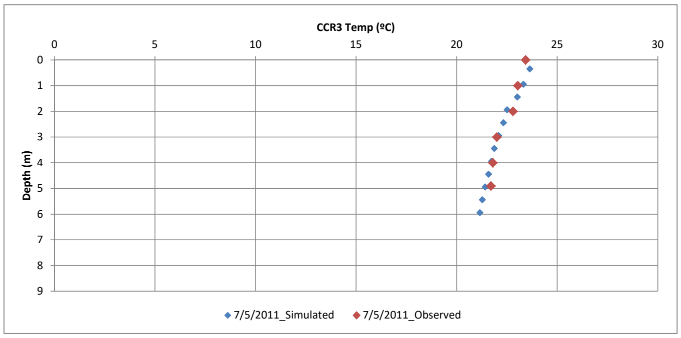

CCR2 Temp (ºC)
Depth (m)
5/31/2011_Simulated
5/31/2011_Observed

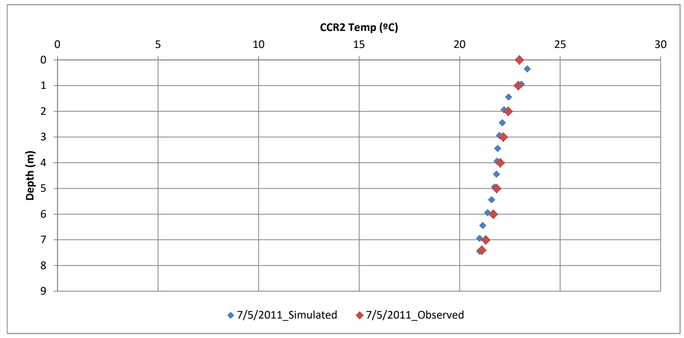

CCR3 Temp (ºC)
Depth (m)
6/7/2011_Simulated
6/7/2011_Observed

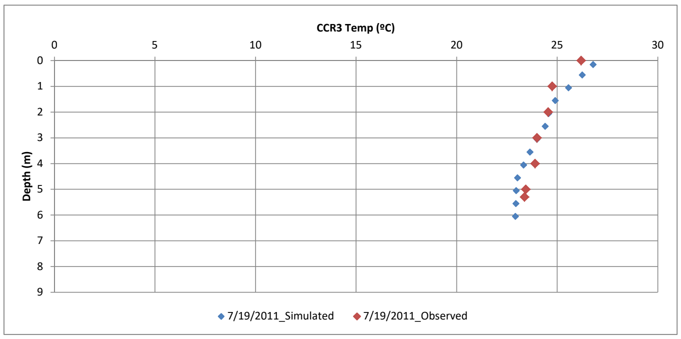

CCR2 Temp (ºC)
Depth (m)
6/7/2011_Simulated
6/7/2011_Observed

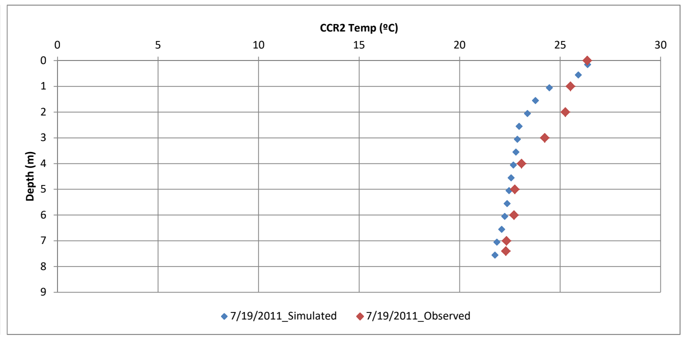

CCR3 Temp (ºC)
Depth (m)
6/21/2011_Simulated
6/21/2011_Observed

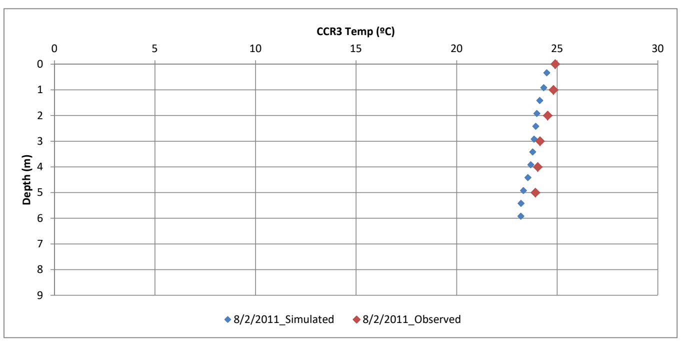

CCR2 Temp (ºC)
Depth (m)
6/21/2011_Simulated
6/21/2011_Observed

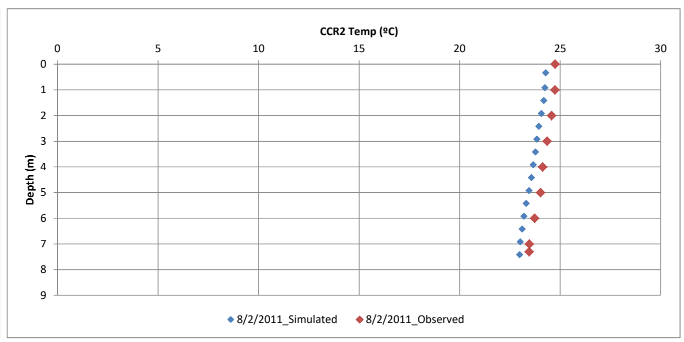

CCR3 Temp (ºC)
Depth (m)
7/5/2011_Simulated
7/5/2011_Observed

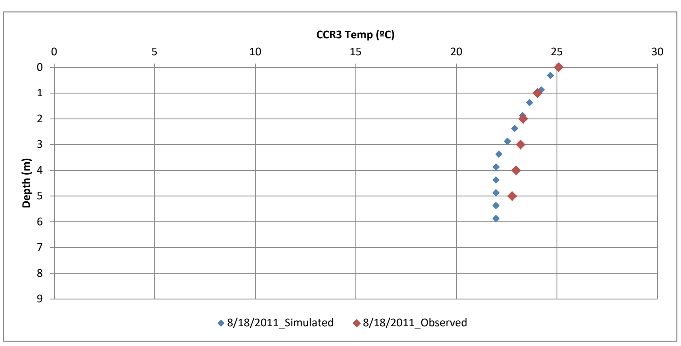

CCR2 Temp (ºC)
Depth (m)
7/5/2011_Simulated
7/5/2011_Observed

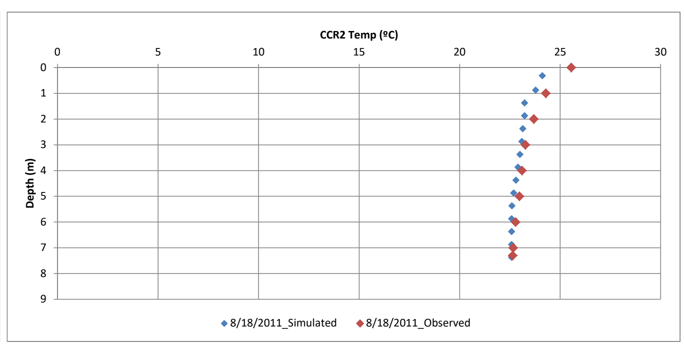

CCR3 Temp (ºC)
Depth (m)
7/19/2011_Simulated
7/19/2011_Observed

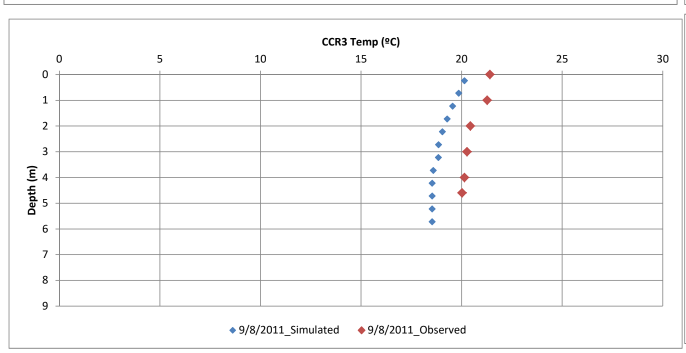

CCR2 Temp (ºC)
Depth (m)
7/19/2011_Simulated
7/19/2011_Observed

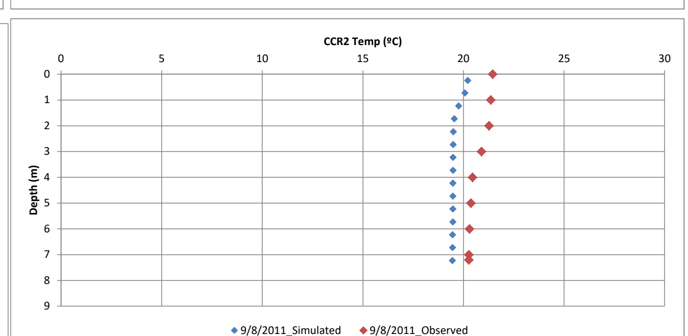

CCR3 Temp (ºC)
Depth (m)
8/2/2011_Simulated
8/2/2011_Observed

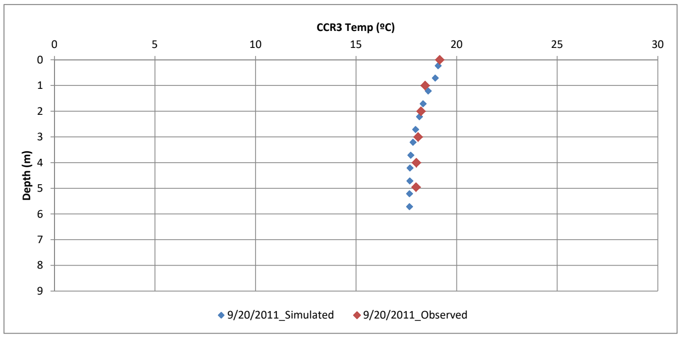

CCR2 Temp (ºC)
Depth (m)
8/2/2011_Simulated
8/2/2011_Observed

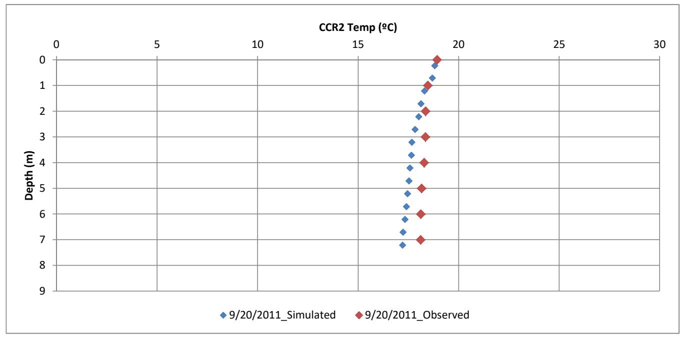

CCR3 Temp (ºC)
Depth (m)
8/18/2011_Simulated
8/18/2011_Observed

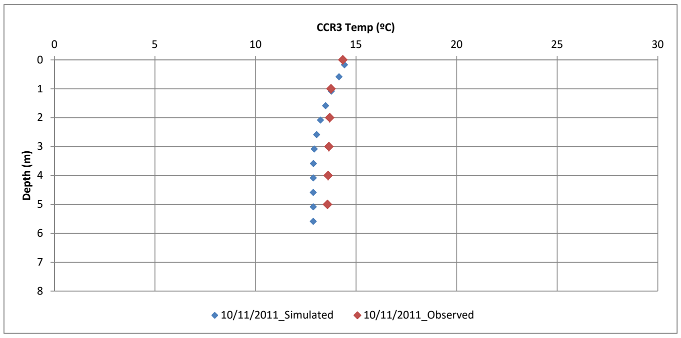

CCR2 Temp (ºC)
Depth (m)
8/18/2011_Simulated
8/18/2011_Observed

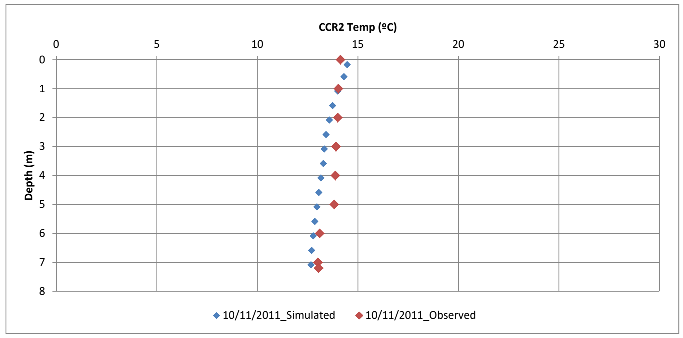

CCR3 Temp (ºC)
Depth (m)
9/8/2011_Simulated
9/8/2011_Observed

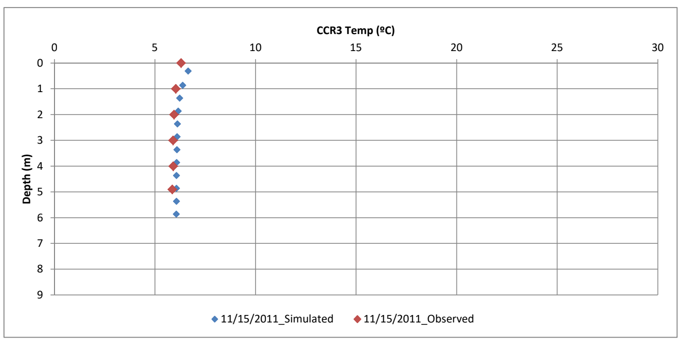

CCR2 Temp (ºC)
Depth (m)
9/8/2011_Simulated
9/8/2011_Observed

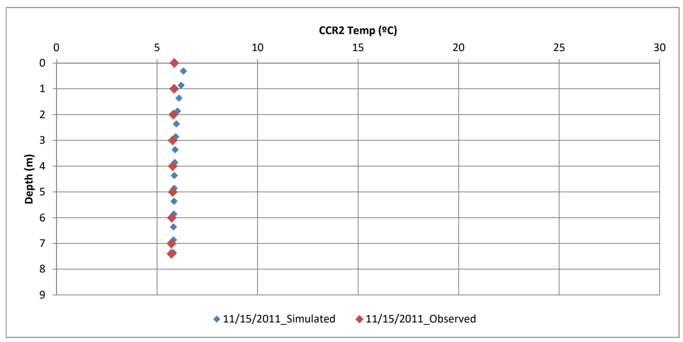

CCR3 Temp (ºC)
Depth (m)
9/20/2011_Simulated
9/20/2011_Observed

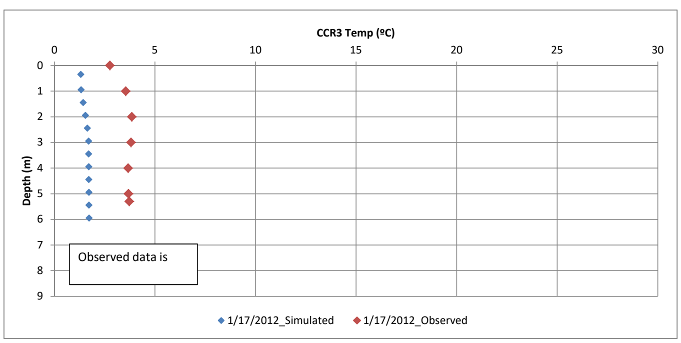

CCR2 Temp (ºC)
Depth (m)
9/20/2011_Simulated
9/20/2011_Observed

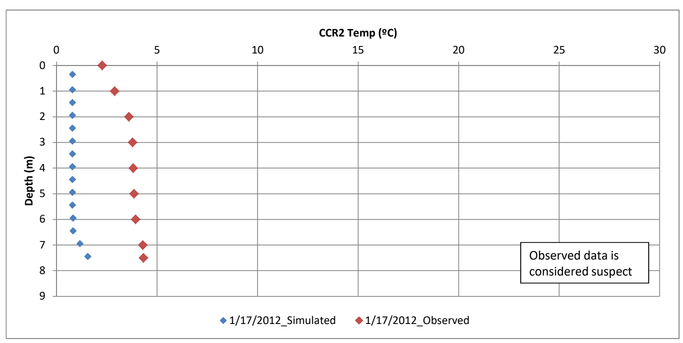

CCR3 Temp (ºC)
Depth (m)
10/11/2011_Simulated
10/11/2011_Observed

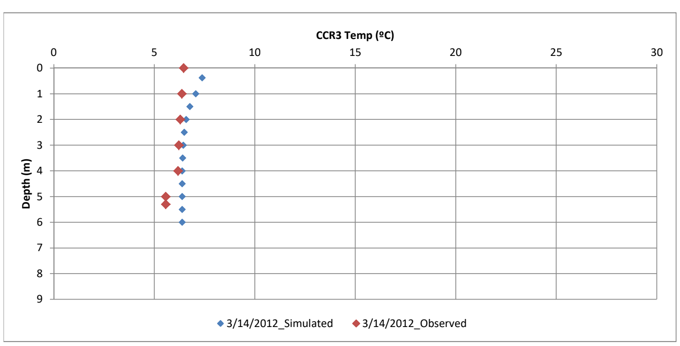

CCR2 Temp (ºC)
Depth (m)
10/11/2011_Simulated
10/11/2011_Observed

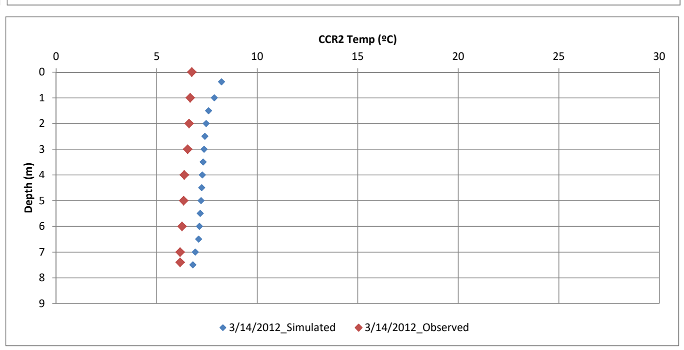

CCR3 Temp (ºC)
Depth (m)
11/15/2011_Simulated
11/15/2011_Observed

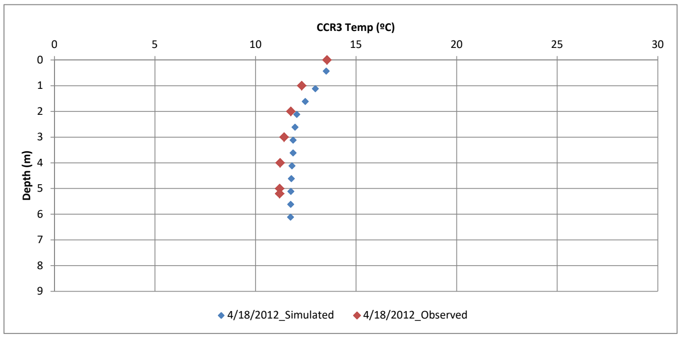

CCR2 Temp (ºC)
Depth (m)
11/15/2011_Simulated
11/15/2011_Observed

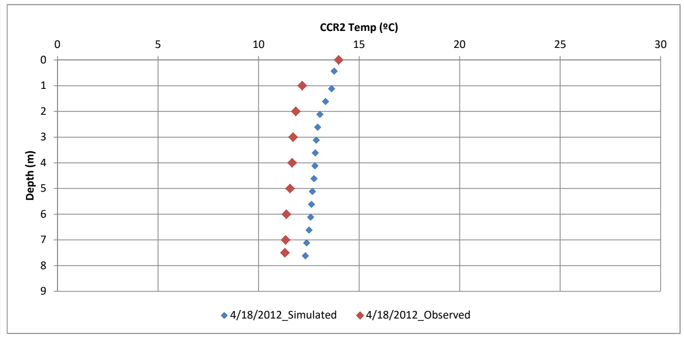

CCR3 Temp (ºC)
Depth (m)
Observed data is
1/17/2012_Simulated
1/17/2012_Observed

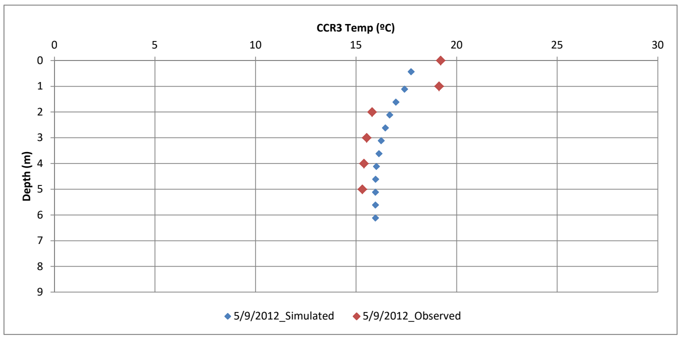

CCR2 Temp (ºC)
Depth (m)
Observed data is considered suspect
1/17/2012_Simulated
1/17/2012_Observed

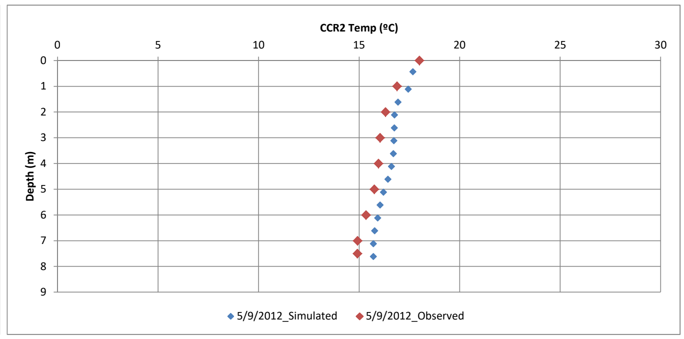

CCR3 Temp (ºC)
Depth (m)
3/14/2012_Simulated
3/14/2012_Observed

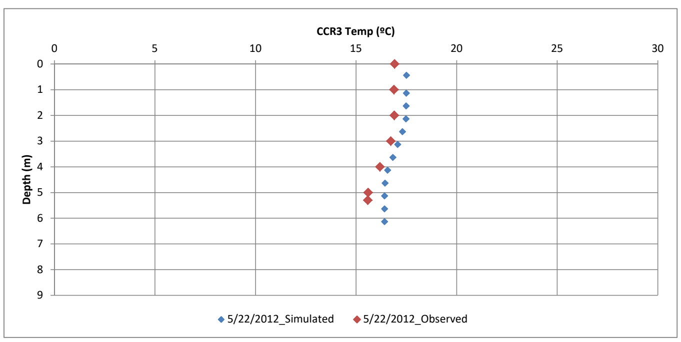

CCR2 Temp (ºC)
Depth (m)
3/14/2012_Simulated
3/14/2012_Observed

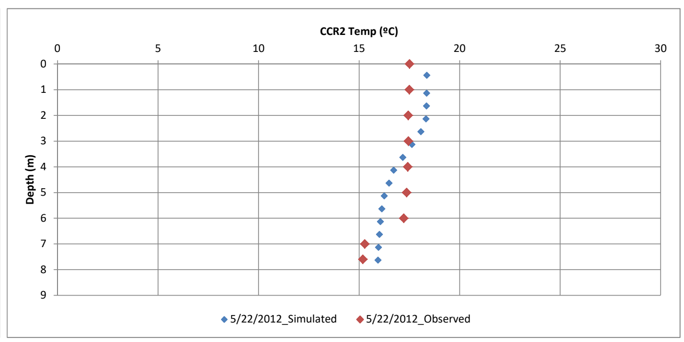

CCR3 Temp (ºC)
Depth (m)
4/18/2012_Simulated
4/18/2012_Observed

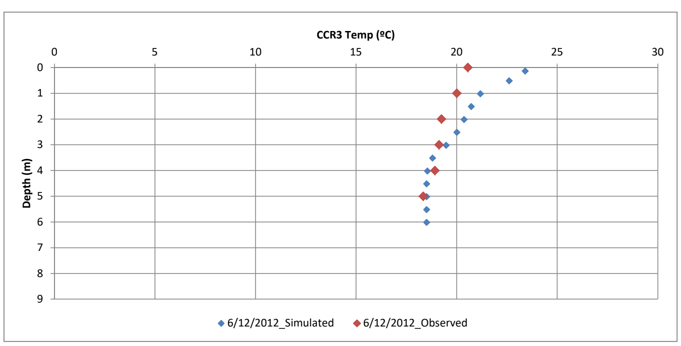

CCR2 Temp (ºC)
Depth (m)
4/18/2012_Simulated
4/18/2012_Observed

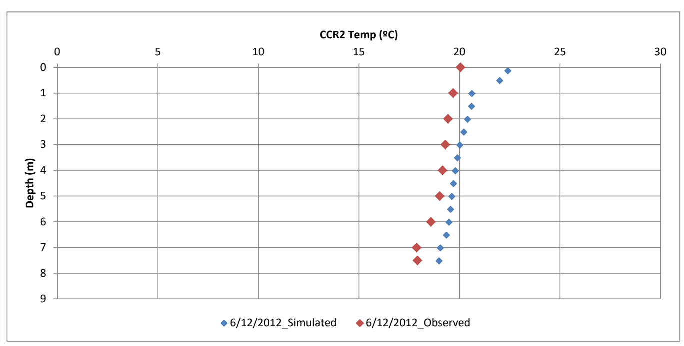

CCR3 Temp (ºC)
Depth (m)
5/9/2012_Simulated
5/9/2012_Observed

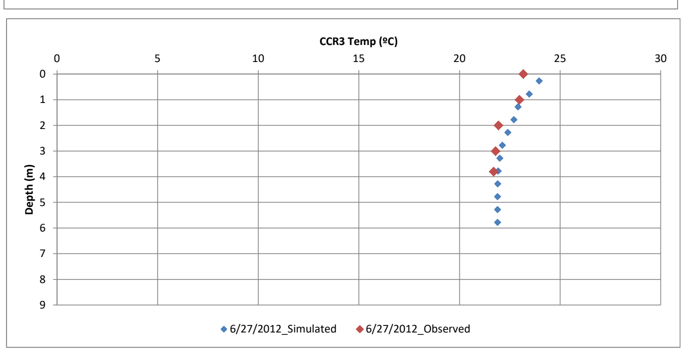

CCR2 Temp (ºC)
Depth (m)
5/9/2012_Simulated
5/9/2012_Observed

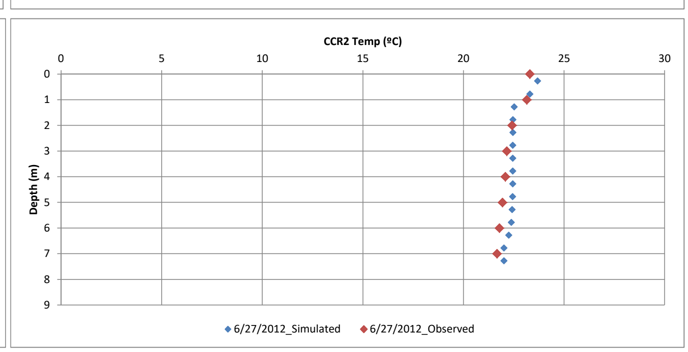

CCR3 Temp (ºC)
Depth (m)
5/22/2012_Simulated
5/22/2012_Observed

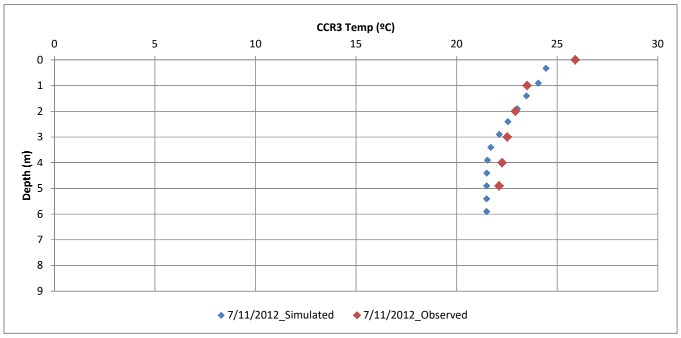

CCR2 Temp (ºC)
Depth (m)
5/22/2012_Simulated
5/22/2012_Observed

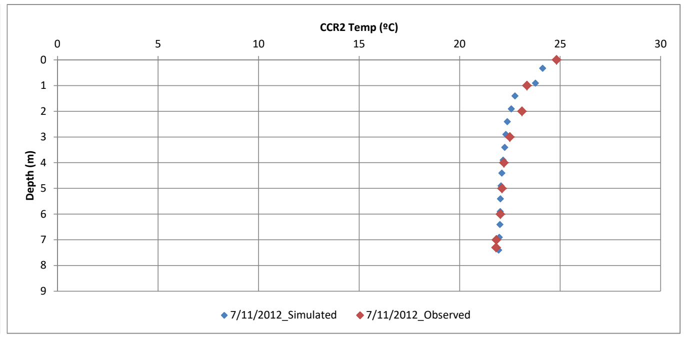

CCR3 Temp (ºC)
Depth (m)
6/12/2012_Simulated
6/12/2012_Observed

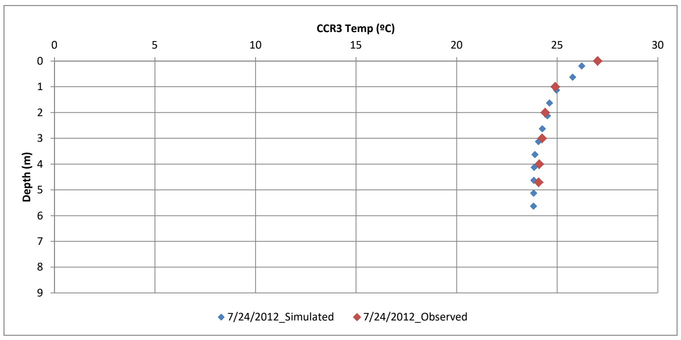

CCR2 Temp (ºC)
Depth (m)
6/12/2012_Simulated
6/12/2012_Observed

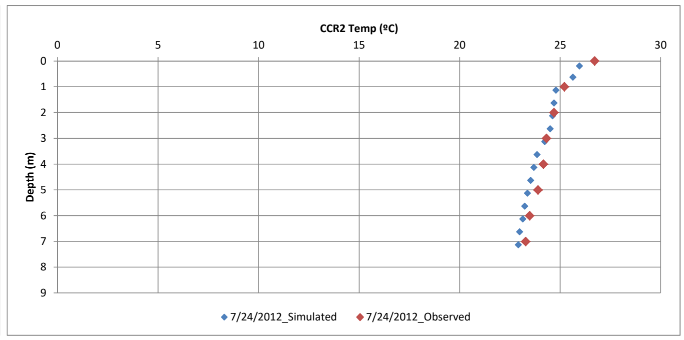

CCR3 Temp (ºC)
Depth (m)
6/27/2012_Simulated
6/27/2012_Observed

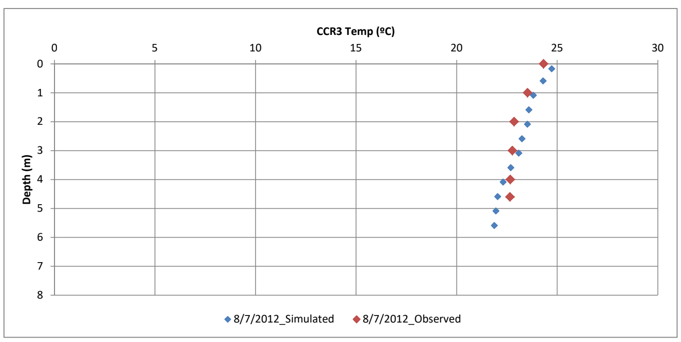

CCR2 Temp (ºC)
Depth (m)
6/27/2012_Simulated
6/27/2012_Observed

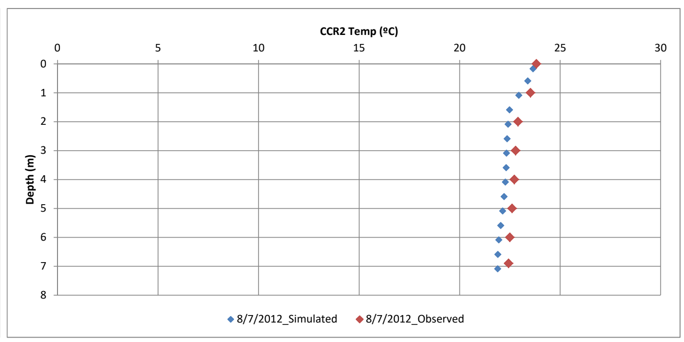

CCR3 Temp (ºC)
Depth (m)
7/11/2012_Simulated
7/11/2012_Observed

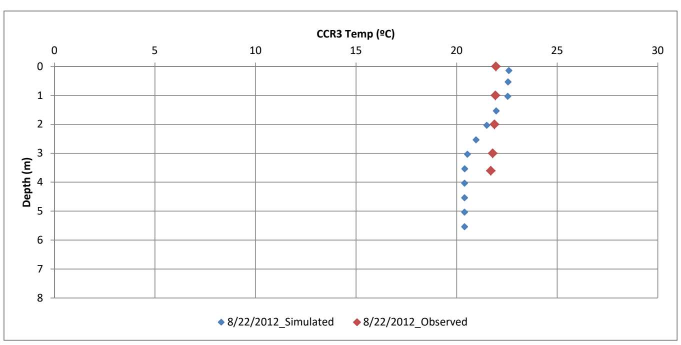

CCR2 Temp (ºC)
Depth (m)
7/11/2012_Simulated
7/11/2012_Observed

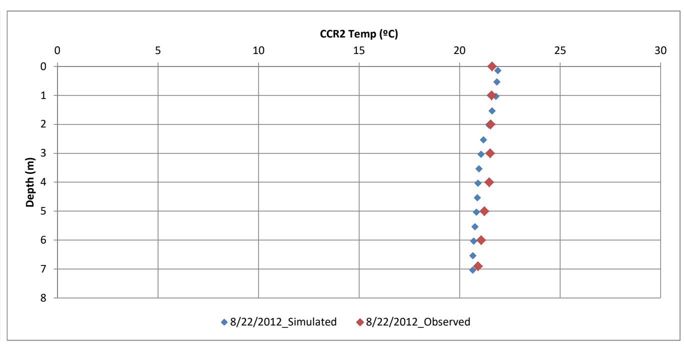

CCR3 Temp (ºC)
Depth (m)
7/24/2012_Simulated
7/24/2012_Observed

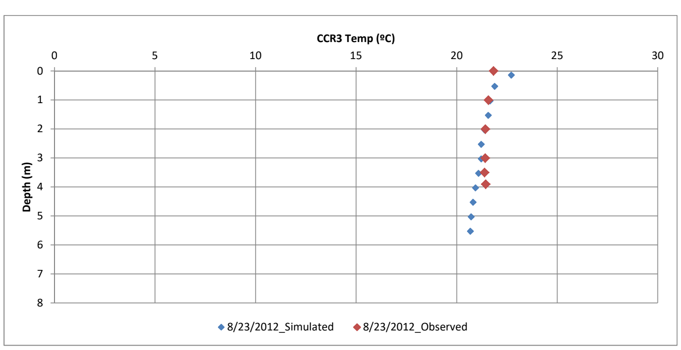

CCR2 Temp (ºC)
Depth (m)
7/24/2012_Simulated
7/24/2012_Observed

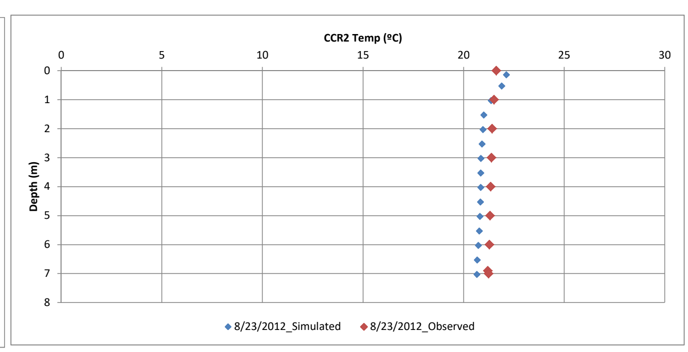

CCR3 Temp (ºC)
Depth (m)
8/7/2012_Simulated
8/7/2012_Observed

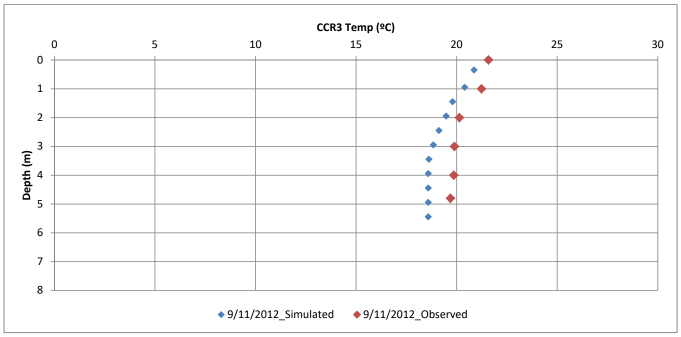

CCR2 Temp (ºC)
Depth (m)
8/7/2012_Simulated
8/7/2012_Observed

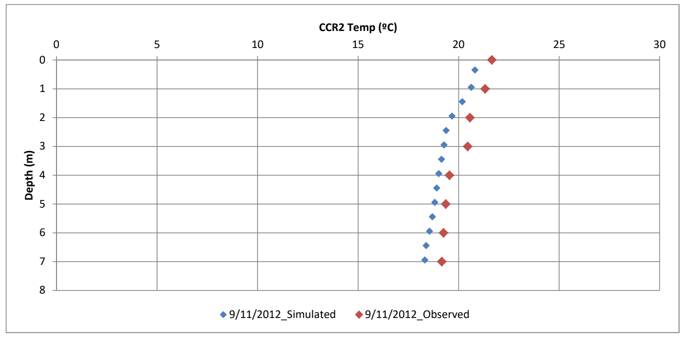

CCR3 Temp (ºC)
Depth (m)
8/22/2012_Simulated
8/22/2012_Observed

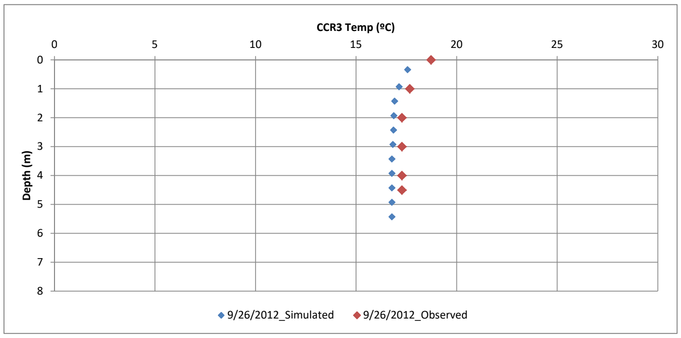

CCR2 Temp (ºC)
Depth (m)
8/22/2012_Simulated
8/22/2012_Observed

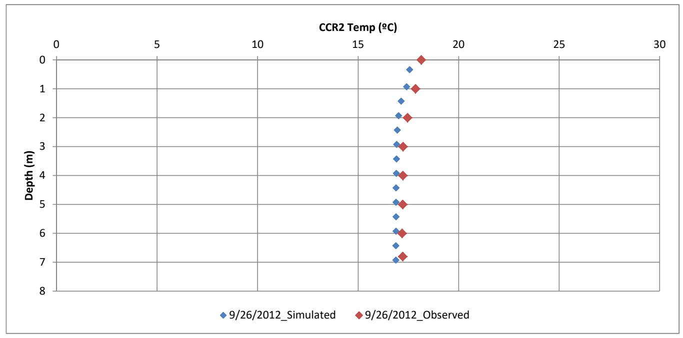

CCR3 Temp (ºC)
Depth (m)
8/23/2012_Simulated
8/23/2012_Observed

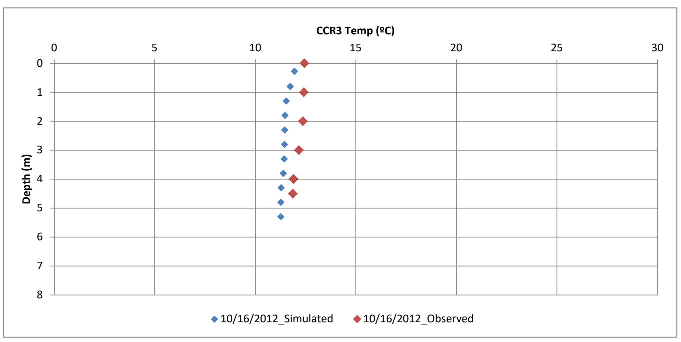

CCR2 Temp (ºC)
Depth (m)
8/23/2012_Simulated
8/23/2012_Observed

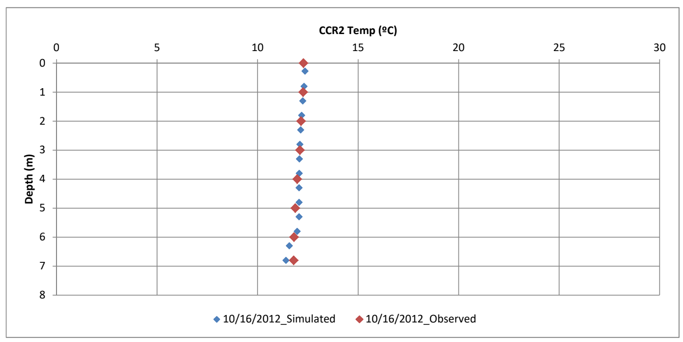

CCR3 Temp (ºC)
Depth (m)
9/11/2012_Simulated
9/11/2012_Observed

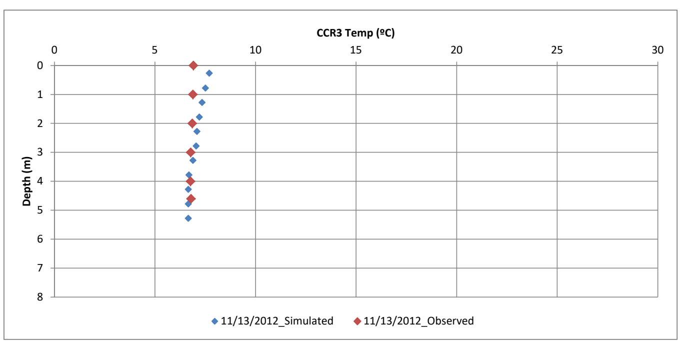

CCR2 Temp (ºC)
Depth (m)
9/11/2012_Simulated
9/11/2012_Observed

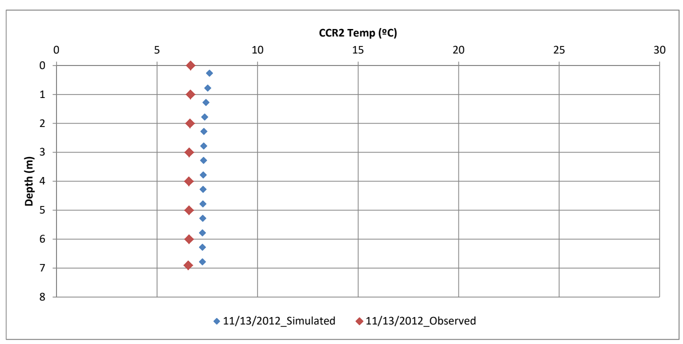

CCR3 Temp (ºC)
Depth (m)
9/26/2012_Simulated
9/26/2012_Observed

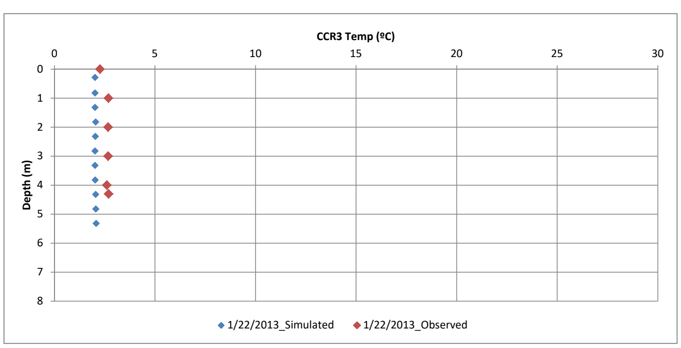

CCR2 Temp (ºC)
Depth (m)
9/26/2012_Simulated
9/26/2012_Observed

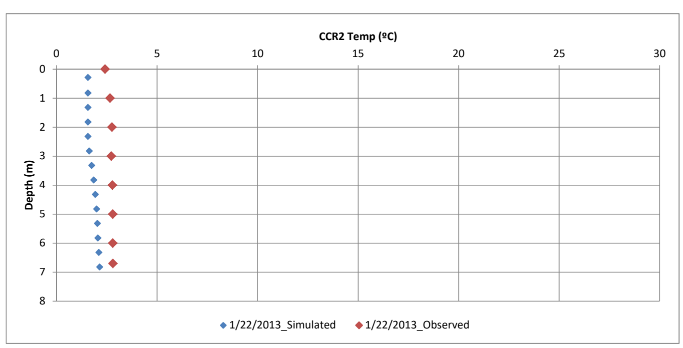

CCR3 Temp (ºC)
Depth (m)
10/16/2012_Simulated
10/16/2012_Observed

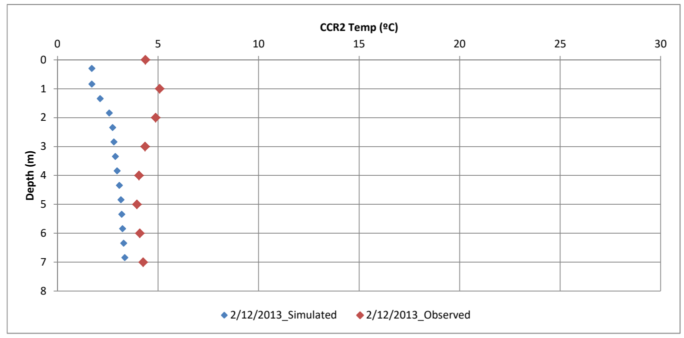

CCR2 Temp (ºC)
Depth (m)
10/16/2012_Simulated
10/16/2012_Observed

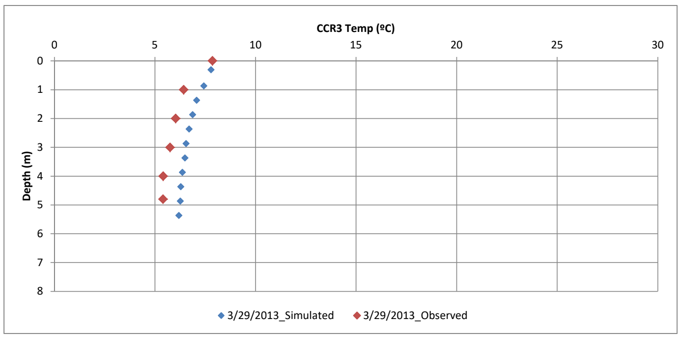

CCR3 Temp (ºC)
Depth (m)
11/13/2012_Simulated
11/13/2012_Observed

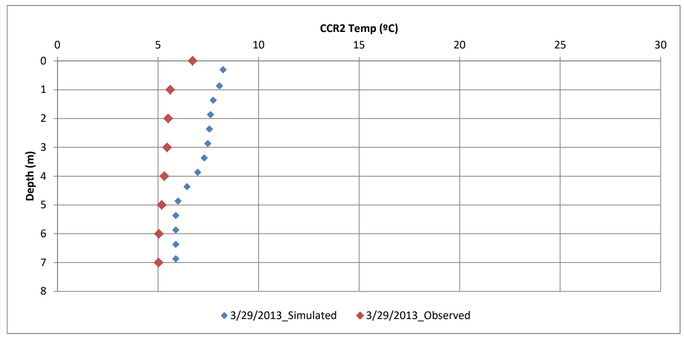

CCR2 Temp (ºC)
Depth (m)
11/13/2012_Simulated
11/13/2012_Observed

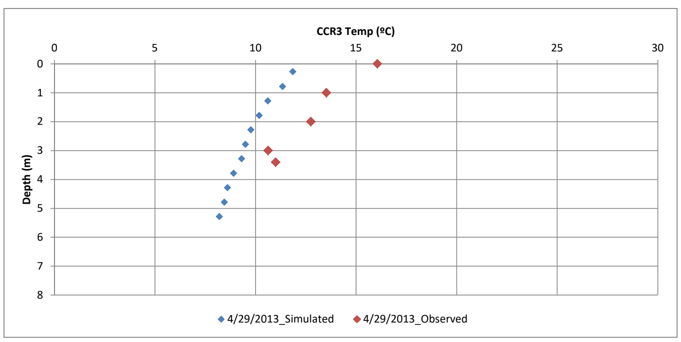

CCR3 Temp (ºC)
Depth (m)
1/22/2013_Simulated
1/22/2013_Observed

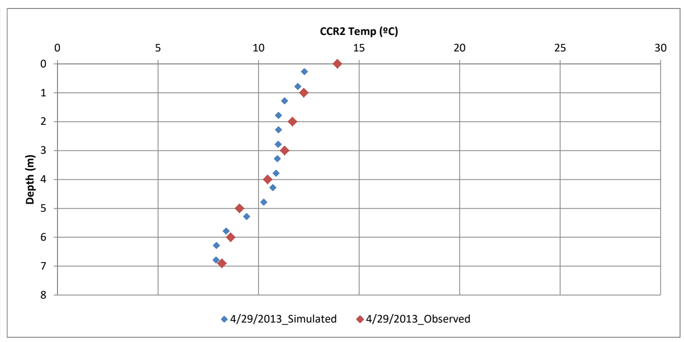

CCR2 Temp (ºC)
Depth (m)
1/22/2013_Simulated
1/22/2013_Observed

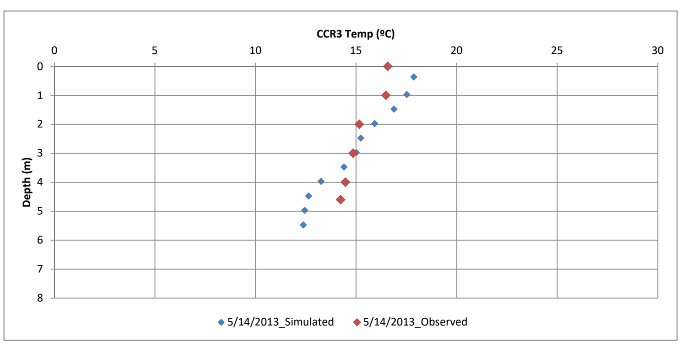

CCR2 Temp (ºC)
Depth (m)
2/12/2013_Simulated
2/12/2013_Observed

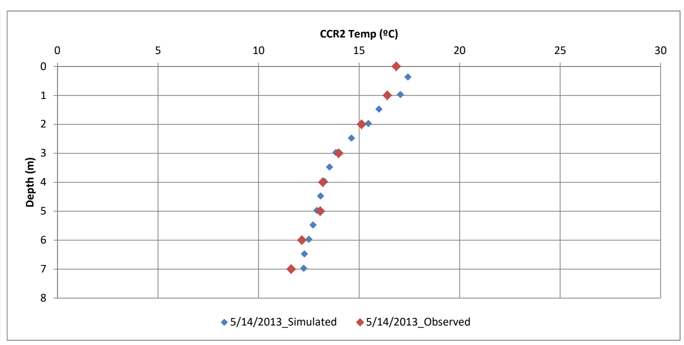

CCR3 Temp (ºC)
Depth (m)
3/29/2013_Simulated
3/29/2013_Observed

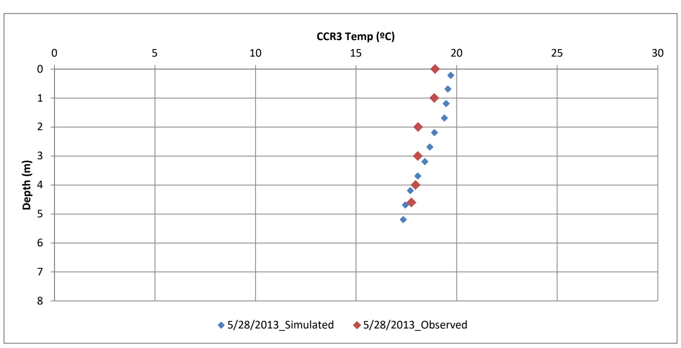

CCR2 Temp (ºC)
Depth (m)
3/29/2013_Simulated
3/29/2013_Observed

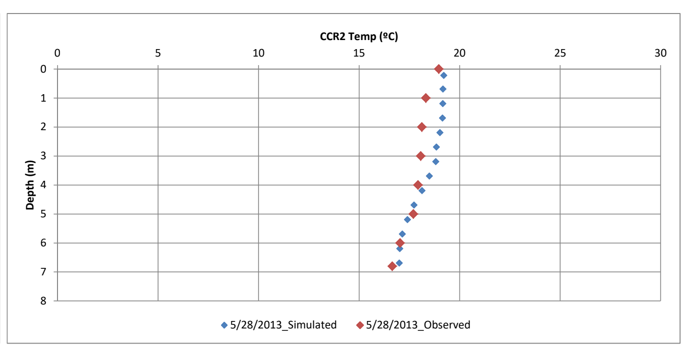

CCR3 Temp (ºC)
Depth (m)
4/29/2013_Simulated
4/29/2013_Observed

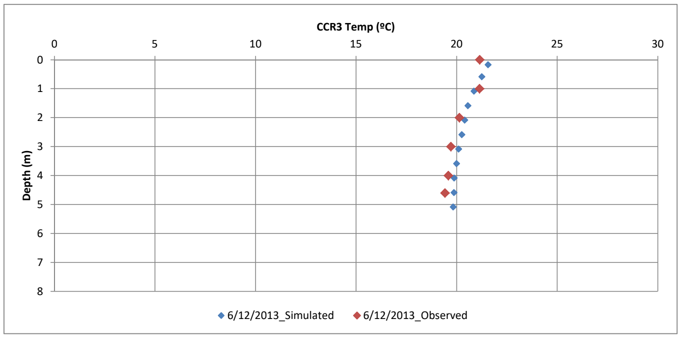

CCR2 Temp (ºC)
Depth (m)
4/29/2013_Simulated
4/29/2013_Observed

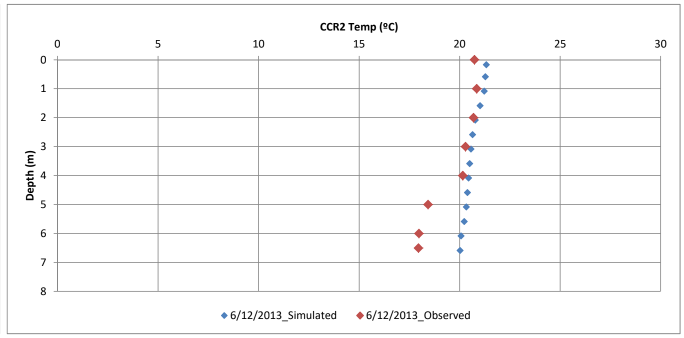

CCR3 Temp (ºC)
Depth (m)
5/14/2013_Simulated
5/14/2013_Observed

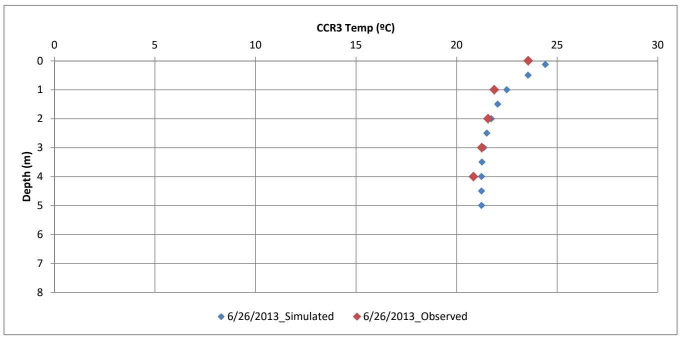

CCR2 Temp (ºC)
Depth (m)
5/14/2013_Simulated
5/14/2013_Observed

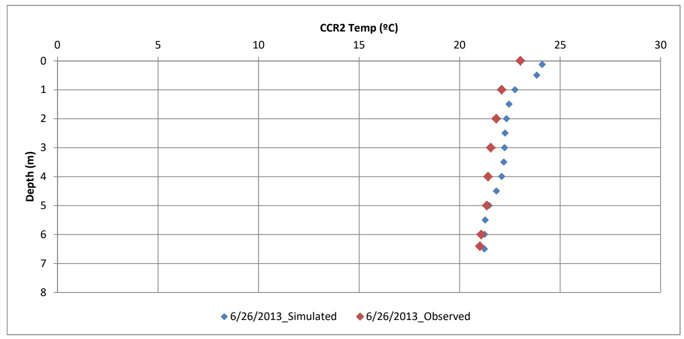

CCR3 Temp (ºC)
Depth (m)
5/28/2013_Simulated
5/28/2013_Observed

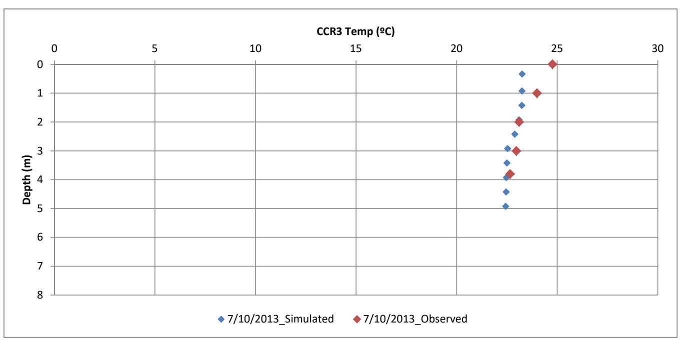

CCR2 Temp (ºC)
Depth (m)
5/28/2013_Simulated
5/28/2013_Observed

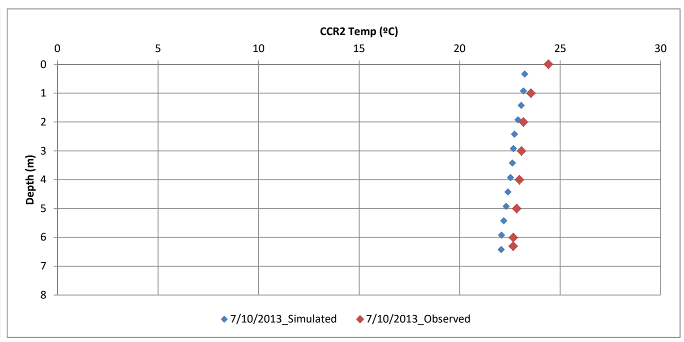

CCR3 Temp (ºC)
0 5 10 15 20 25 30
Depth (m)
0 1 2 3 4 5 6 7 8
6/12/2013_Simulated
6/12/2013_Observed

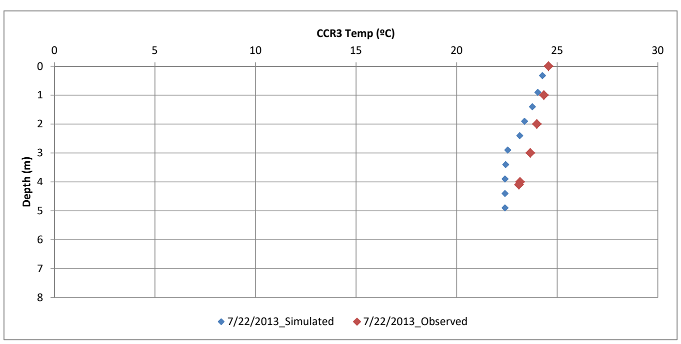

CCR2 Temp (ºC)
0 5 10 15 20 25 30
Depth (m)
0 1 2 3 4 5 6 7 8
6/12/2013_Simulated
6/12/2013_Observed

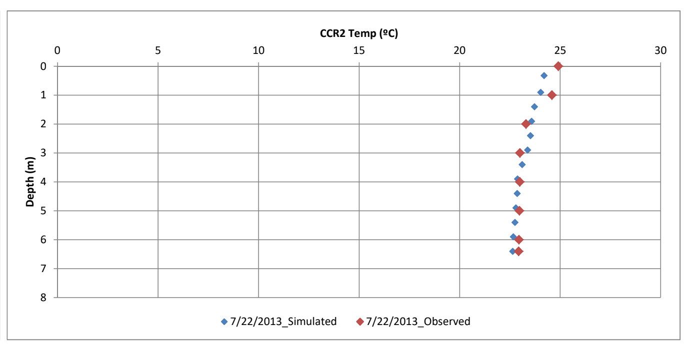

CCR3 Temp (ºC)
0 5 10 15 20 25 30
Depth (m)
0 1 2 3 4 5 6 7 8
6/26/2013_Simulated
6/26/2013_Observed

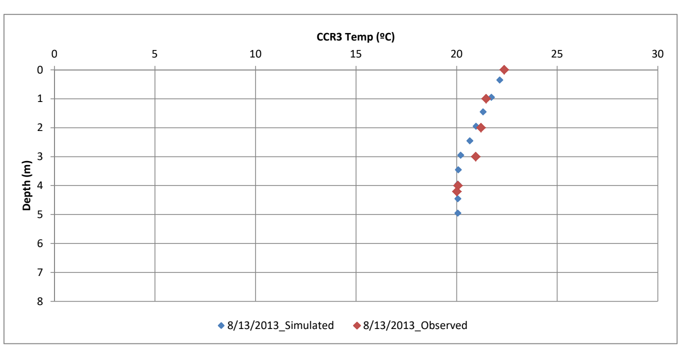

CCR2 Temp (ºC)
0 5 10 15 20 25 30
Depth (m)
0 1 2 3 4 5 6 7 8
6/26/2013_Simulated
6/26/2013_Observed

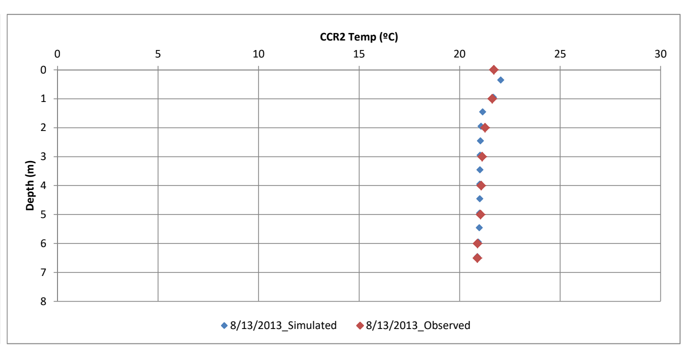

CCR3 Temp (ºC)
0 5 10 15 20 25 30
Depth (m)
0 1 2 3 4 5 6 7 8
7/10/2013_Simulated
7/10/2013_Observed

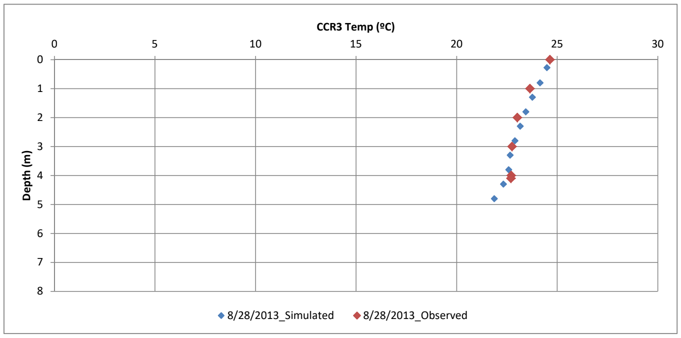

CCR2 Temp (ºC)
0 5 10 15 20 25 30
Depth (m)
0 1 2 3 4 5 6 7 8
7/10/2013_Simulated
7/10/2013_Observed

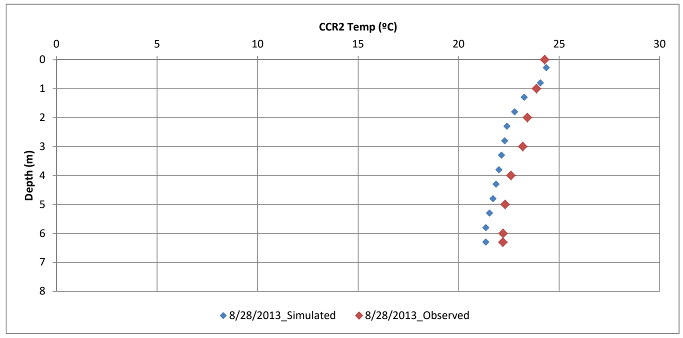

CCR3 Temp (ºC)
0 5 10 15 20 25 30
Depth (m)
0 1 2 3 4 5 6 7 8
7/22/2013_Simulated
7/22/2013_Observed

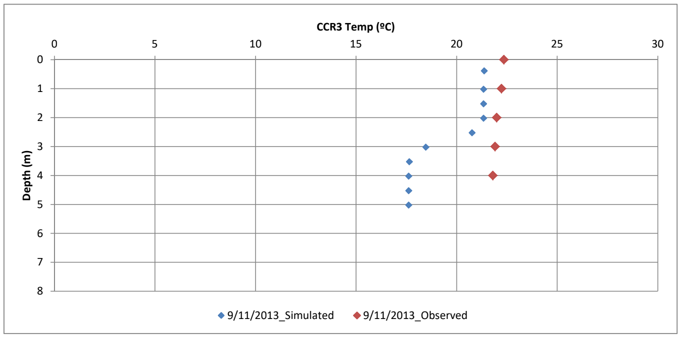

CCR2 Temp (ºC)
0 5 10 15 20 25 30
Depth (m)
0 1 2 3 4 5 6 7 8
7/22/2013_Simulated
7/22/2013_Observed

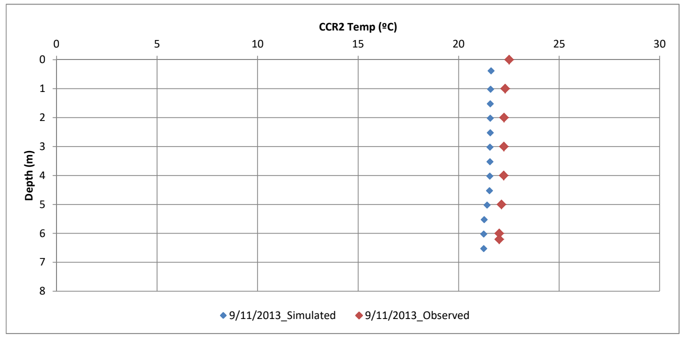

CCR3 Temp (ºC)
0 5 10 15 20 25 30
Depth (m)
0 1 2 3 4 5 6 7 8
8/13/2013_Simulated
8/13/2013_Observed

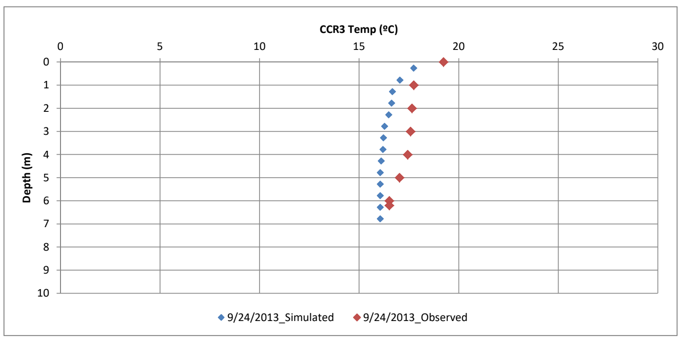

CCR2 Temp (ºC)
0 5 10 15 20 25 30
Depth (m)
0 1 2 3 4 5 6 7 8
8/13/2013_Simulated
8/13/2013_Observed

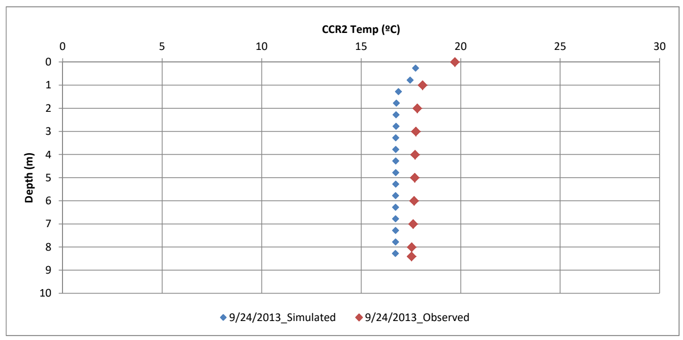

CCR3 Temp (ºC)
Depth (m)
8/28/2013_Simulated
8/28/2013_Observed

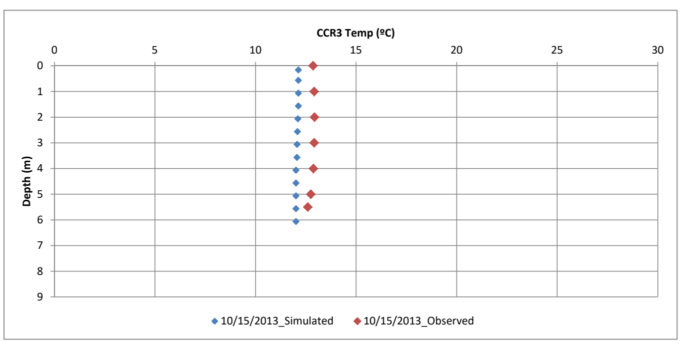

CCR2 Temp (ºC)
Depth (m)
8/28/2013_Simulated
8/28/2013_Observed

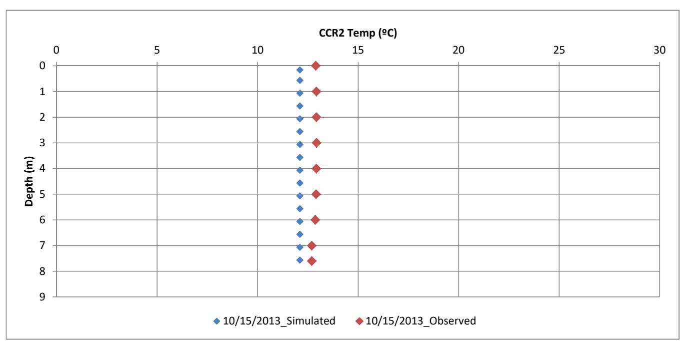

CCR3 Temp (ºC)
Depth (m)
9/11/2013_Simulated
9/11/2013_Observed

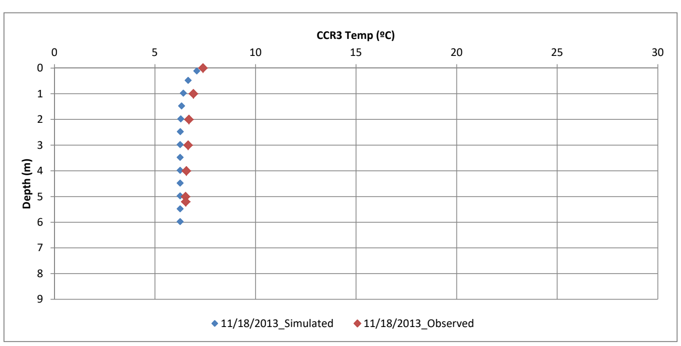

CCR2 Temp (ºC)
Depth (m)
9/11/2013_Simulated
9/11/2013_Observed

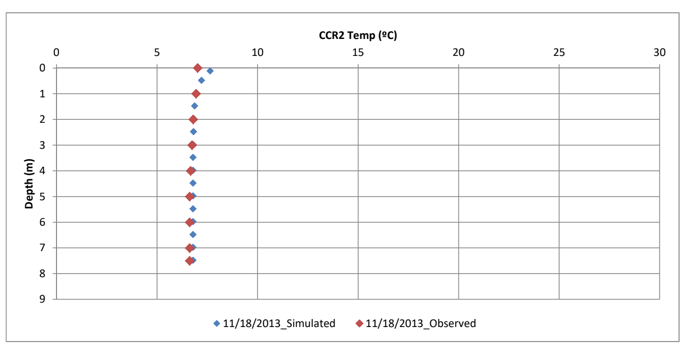

CCR3 Temp (ºC)
Depth (m)
9/24/2013_Simulated
9/24/2013_Observed

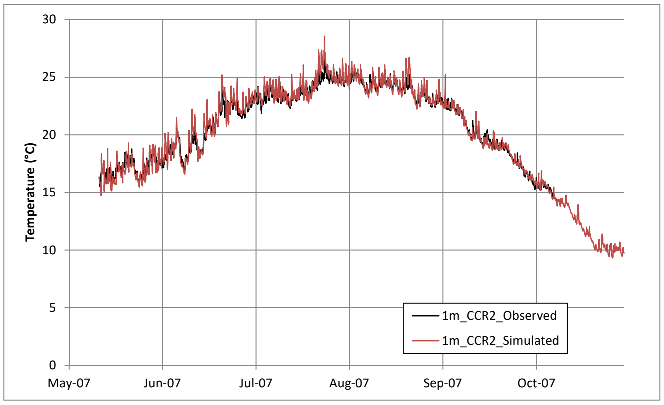

CCR2 Temp (ºC)
Depth (m)
9/24/2013_Simulated
9/24/2013_Observed

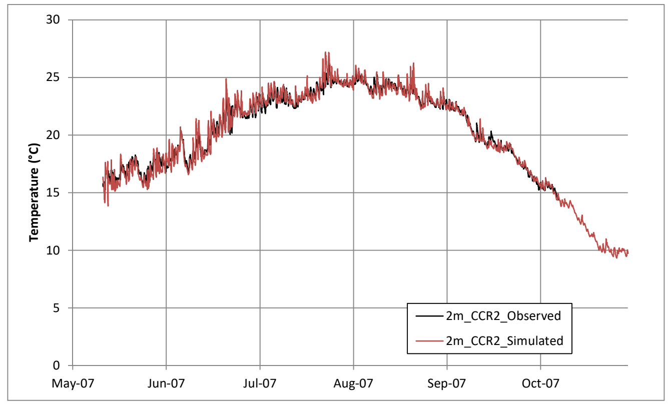

CCR3 Temp (ºC)
Depth (m)
10/15/2013_Simulated
10/15/2013_Observed

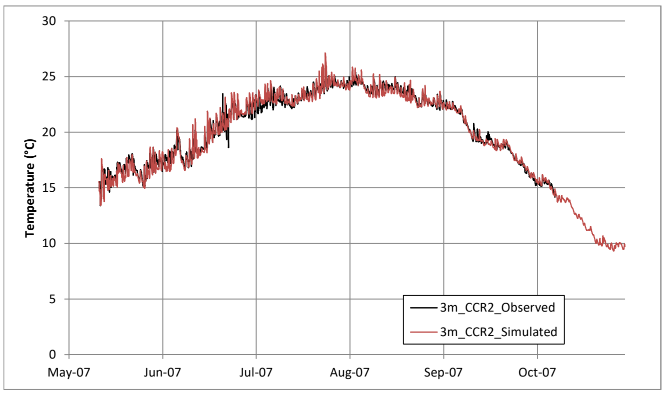

CCR2 Temp (ºC)
Depth (m)
10/15/2013_Simulated
10/15/2013_Observed

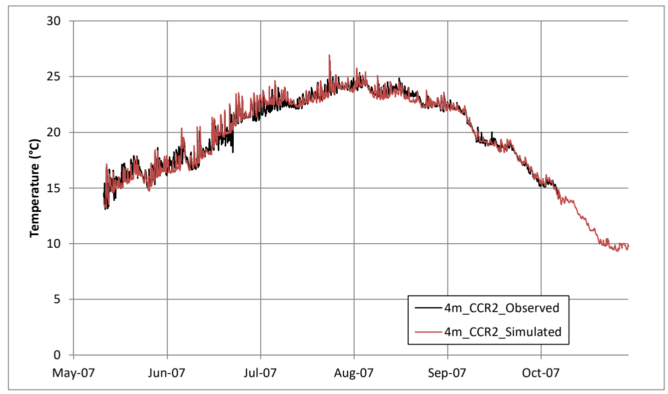

CCR3 Temp (ºC)
Depth (m)
11/18/2013_Simulated
11/18/2013_Observed

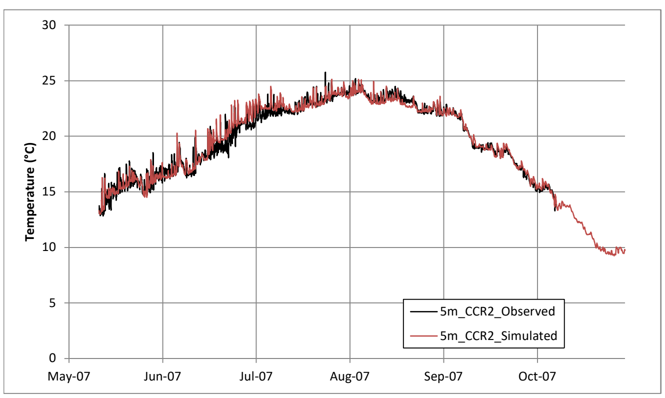

CCR2 Temp (ºC)
Depth (m)
11/18/2013_Simulated
11/18/2013_Observed

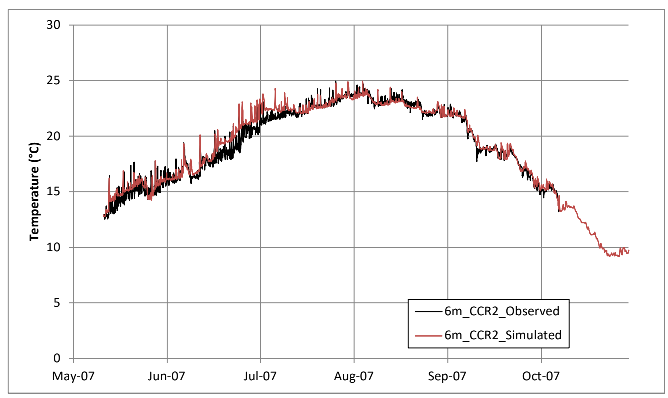

Temperature (°C)
1m_CCR2_Observed
1m_CCR2_Simulated
May-07
Jun-07
Jul-07
Aug-07
Sep-07
Oct-07

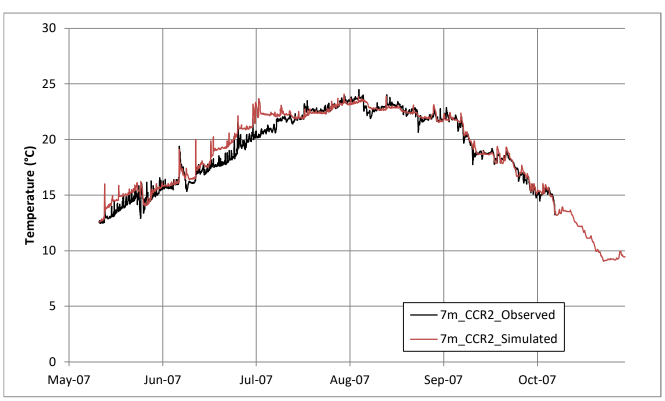

Temperature (°C)
2m_CCR2_Observed
2m_CCR2_Simulated
May-07
Jun-07
Jul-07
Aug-07
Sep-07
Oct-07

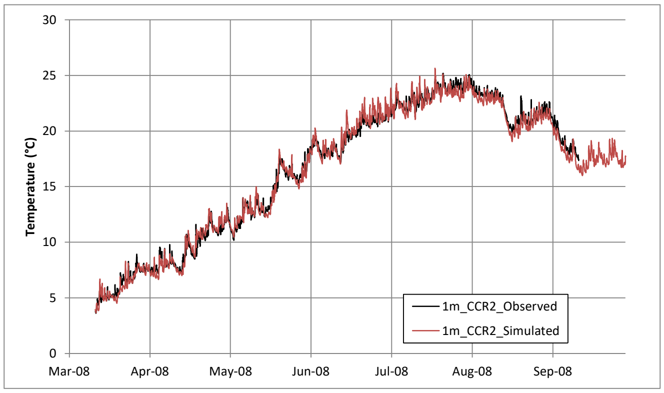

Temperature (°C)
3m_CCR2_Observed
3m_CCR2_Simulated
May-07
Jun-07
Jul-07
Aug-07
Sep-07
Oct-07

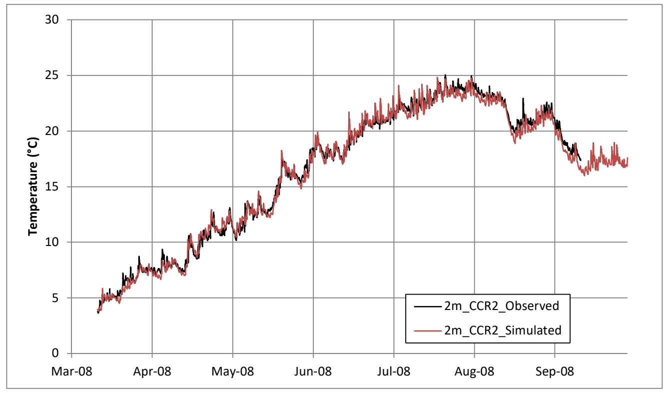

Temperature (°C)
4m_CCR2_Observed
4m_CCR2_Simulated
May-07
Jun-07
Jul-07
Aug-07
Sep-07
Oct-07

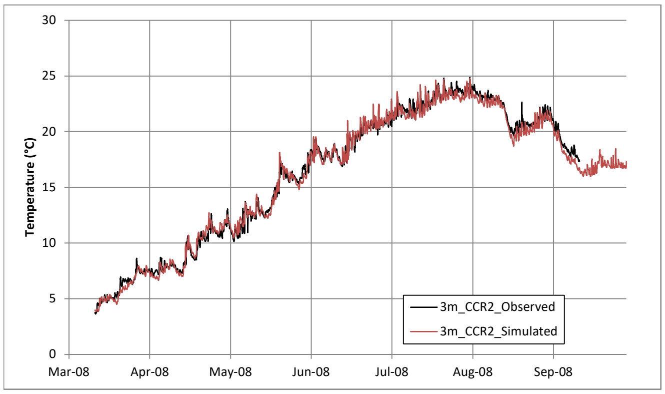

Temperature (°C)
5m_CCR2_Observed
5m_CCR2_Simulated
May-07
Jun-07
Jul-07
Aug-07
Sep-07
Oct-07

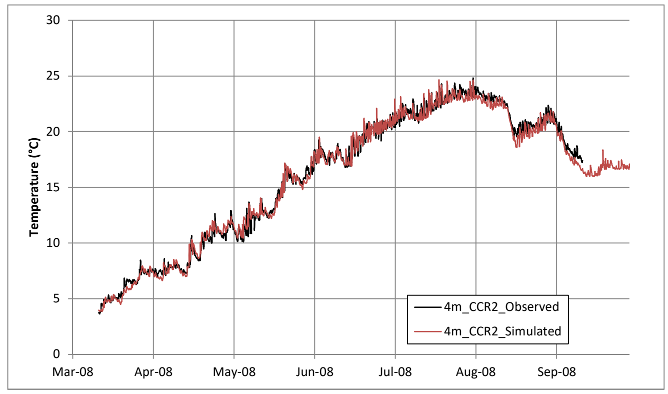

Temperature (°C)
6m_CCR2_Observed
6m_CCR2_Simulated
May-07
Jun-07
Jul-07
Aug-07
Sep-07
Oct-07

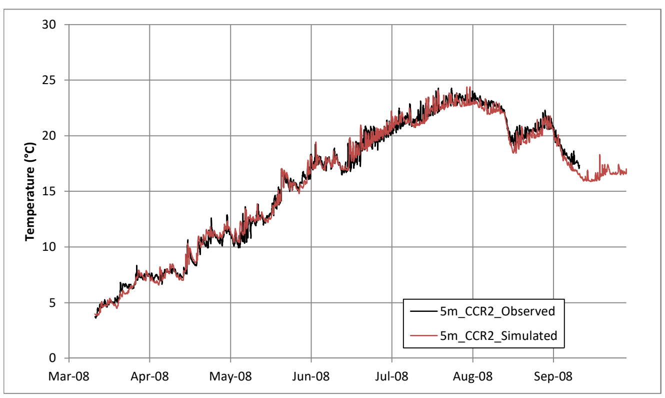

Temperature (°C)
7m_CCR2_Observed
7m_CCR2_Simulated
May-07
Jun-07
Jul-07
Aug-07
Sep-07
Oct-07

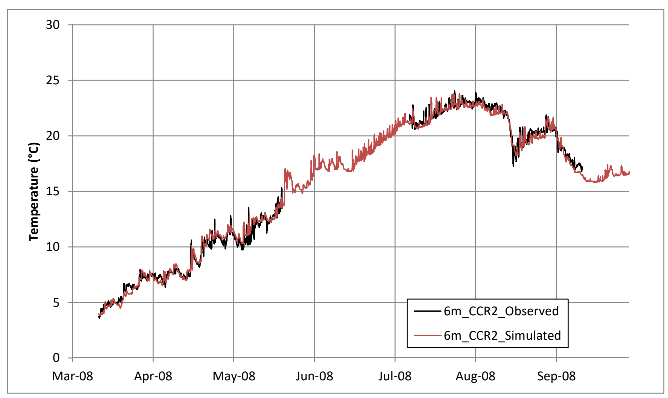

Temperature (°C)
1m_CCR2_Observed
1m_CCR2_Simulated
Mar-08
Apr-08
May-08
Jun-08
Jul-08
Aug-08
Sep-08

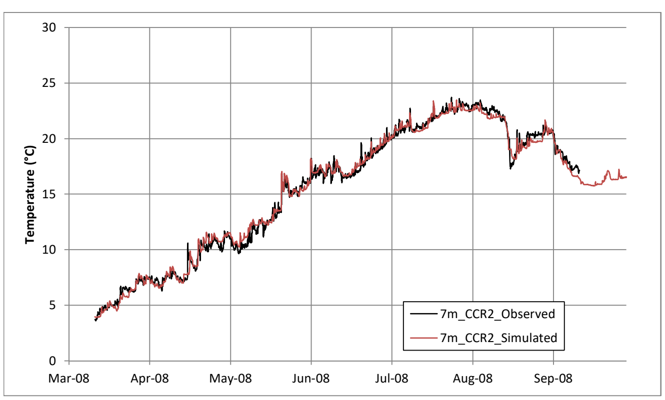

Temperature (°C)
2m_CCR2_Observed
2m_CCR2_Simulated
Mar-08
Apr-08
May-08
Jun-08
Jul-08
Aug-08
Sep-08

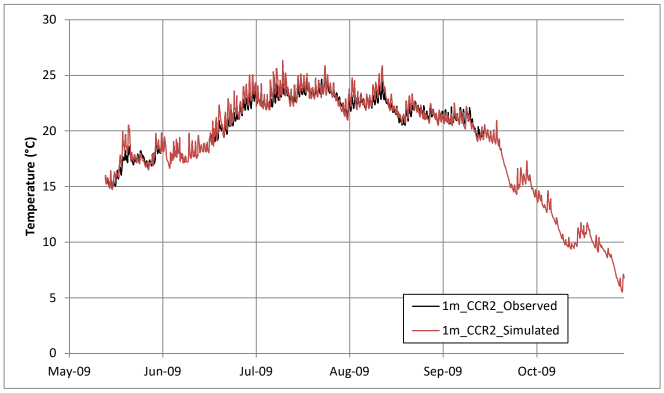

Temperature (°C)
3m_CCR2_Observed
3m_CCR2_Simulated
Mar-08
Apr-08
May-08
Jun-08
Jul-08
Aug-08
Sep-08

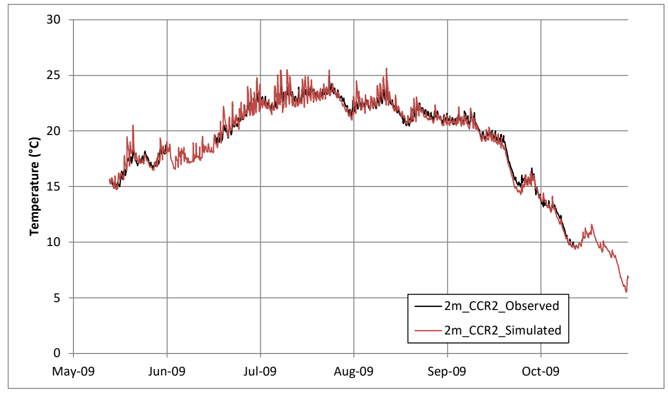

Temperature (°C)
4m_CCR2_Observed
4m_CCR2_Simulated
Mar-08
Apr-08
May-08
Jun-08
Jul-08
Aug-08
Sep-08

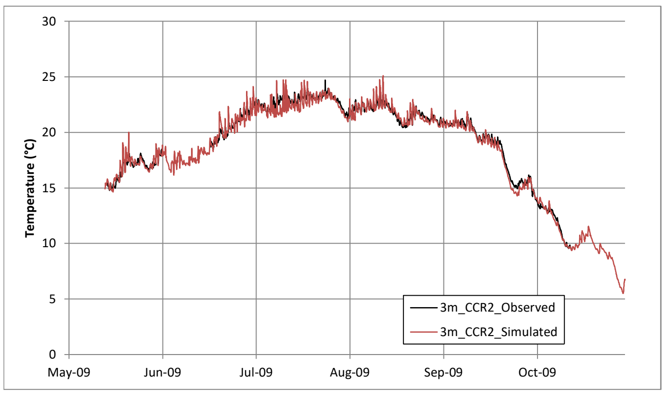

Temperature (°C)
5m_CCR2_Observed
5m_CCR2_Simulated
Mar-08
Apr-08
May-08
Jun-08
Jul-08
Aug-08
Sep-08

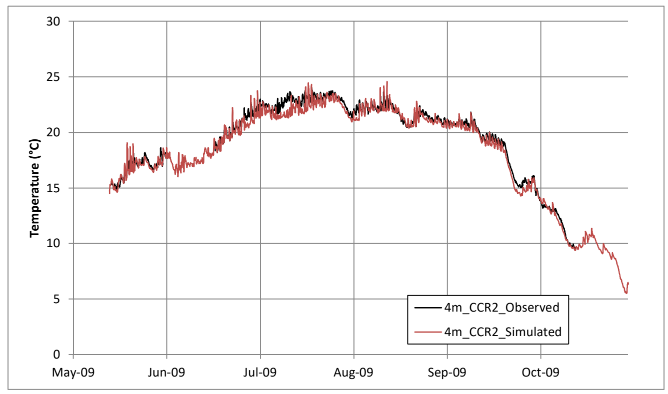

Temperature (°C)
6m_CCR2_Observed
6m_CCR2_Simulated
Mar-08
Apr-08
May-08
Jun-08
Jul-08
Aug-08
Sep-08

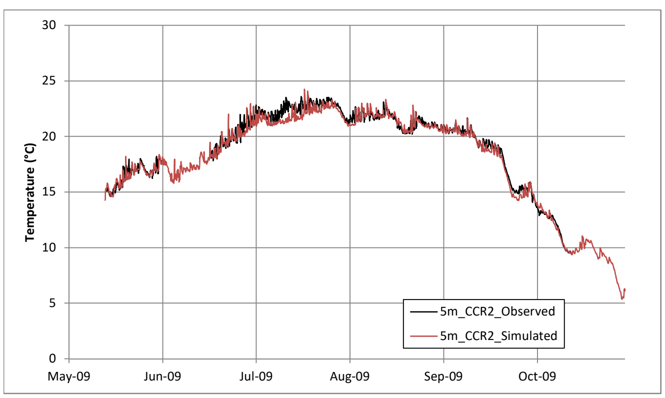

Temperature (°C)
7m_CCR2_Observed
7m_CCR2_Simulated
Mar-08
Apr-08
May-08
Jun-08
Jul-08
Aug-08
Sep-08

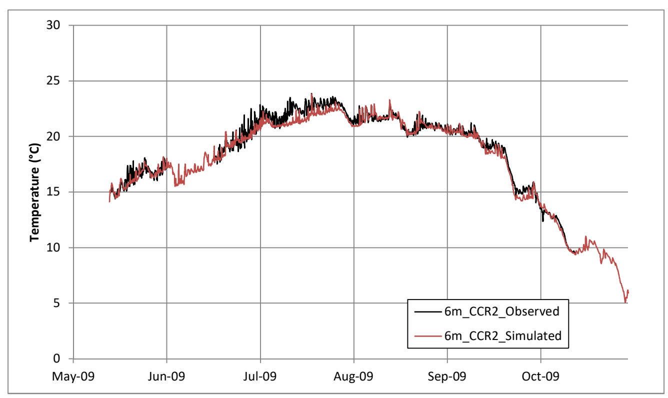

Temperature (°C)
30
25
20
15
10
5
0
May-09
Jun-09
Jul-09
Aug-09
Sep-09
Oct-09
1m_CCR2_Observed
1m_CCR2_Simulated

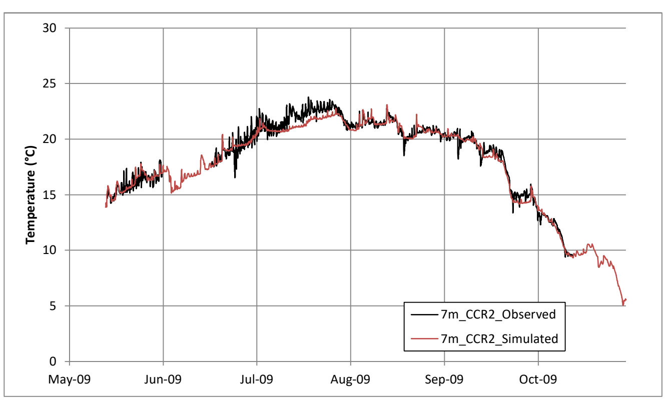

Temperature (°C)
30
25
20
15
10
5
0
May-09
Jun-09
Jul-09
Aug-09
Sep-09
Oct-09
2m_CCR2_Observed
2m_CCR2_Simulated

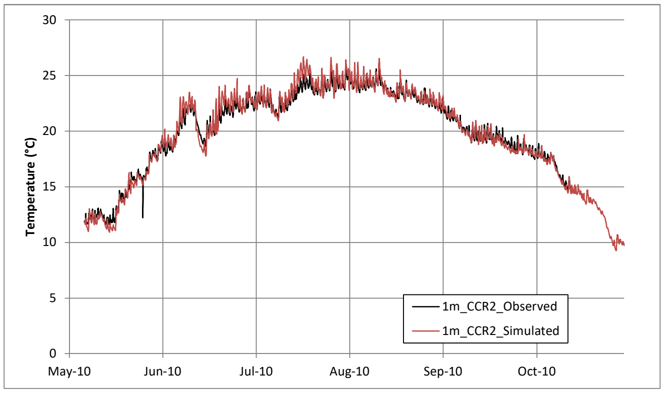

Temperature (°C)
30
25
20
15
10
5
0
May-09
Jun-09
Jul-09
Aug-09
Sep-09
Oct-09
3m_CCR2_Observed
3m_CCR2_Simulated

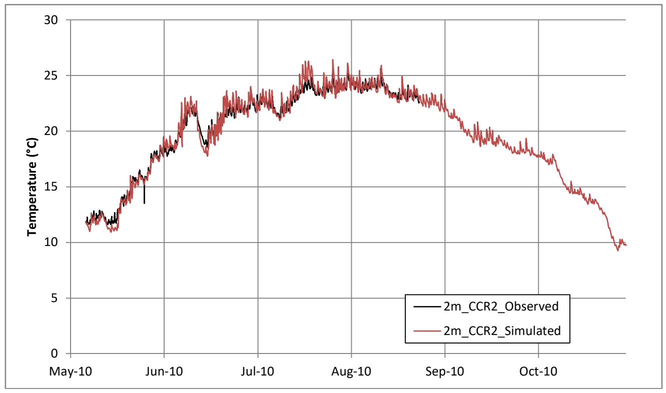

Temperature (°C)
30
25
20
15
10
5
0
May-09
Jun-09
Jul-09
Aug-09
Sep-09
Oct-09
4m_CCR2_Observed
4m_CCR2_Simulated

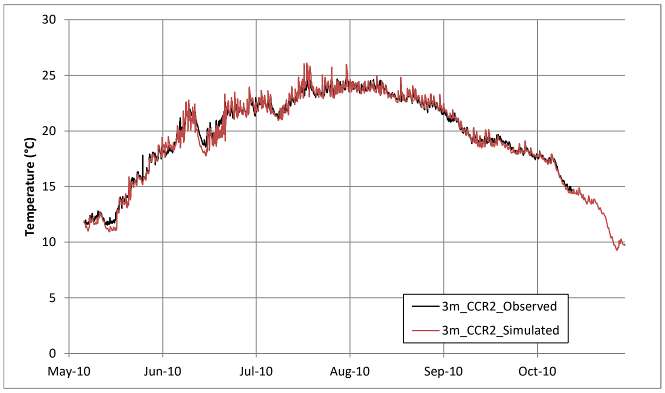

Temperature (°C)
30
25
20
15
10
5
0
May-09
Jun-09
Jul-09
Aug-09
Sep-09
Oct-09
5m_CCR2_Observed
5m_CCR2_Simulated

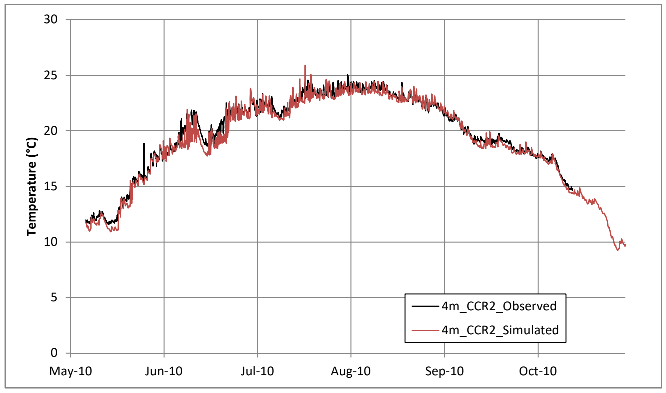

Temperature (°C)
30
25
20
15
10
5
0
May-09
Jun-09
Jul-09
Aug-09
Sep-09
Oct-09
6m_CCR2_Observed
6m_CCR2_Simulated

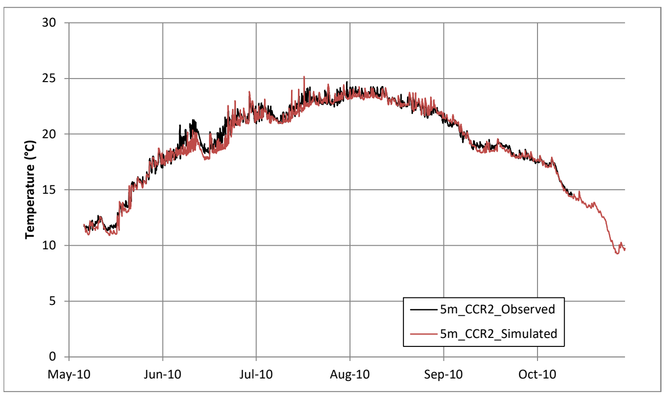

Temperature (°C)
30
25
20
15
10
5
0
May-09
Jun-09
Jul-09
Aug-09
Sep-09
Oct-09
7m_CCR2_Observed
7m_CCR2_Simulated

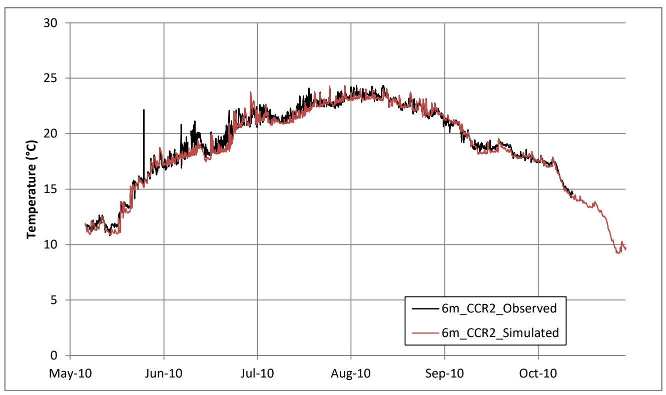

Temperature (°C)
1m_CCR2_Observed
1m_CCR2_Simulated
May-10
Jun-10
Jul-10
Aug-10
Sep-10
Oct-10

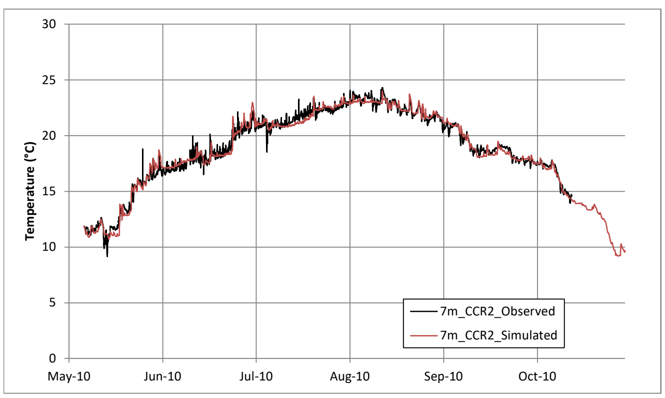

Temperature (°C)
2m_CCR2_Observed
2m_CCR2_Simulated
May-10
Jun-10
Jul-10
Aug-10
Sep-10
Oct-10

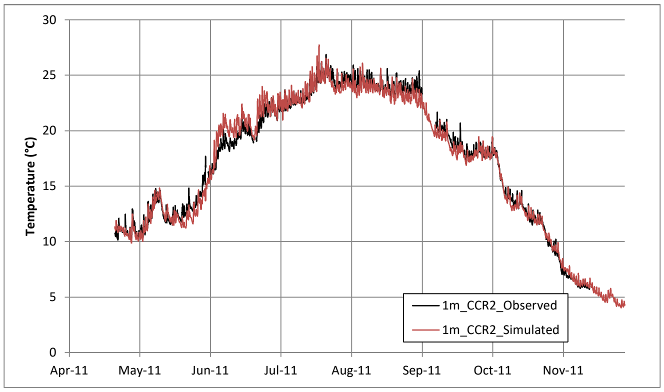

Temperature (°C)
3m_CCR2_Observed
3m_CCR2_Simulated
May-10
Jun-10
Jul-10
Aug-10
Sep-10
Oct-10

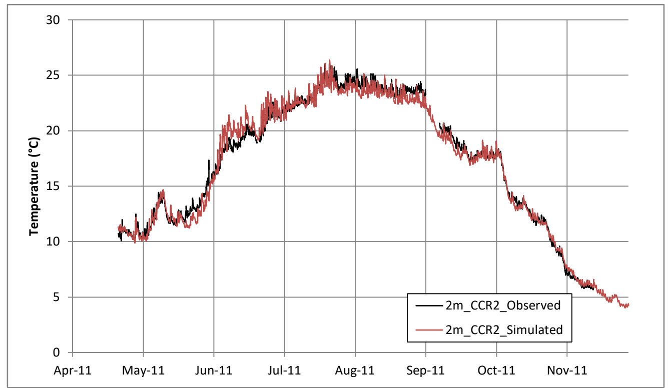

Temperature (°C)
4m_CCR2_Observed
4m_CCR2_Simulated
May-10
Jun-10
Jul-10
Aug-10
Sep-10
Oct-10

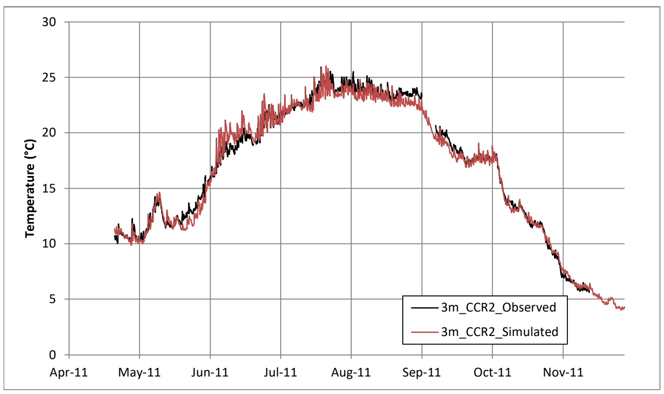

Temperature (°C)
5m_CCR2_Observed
5m_CCR2_Simulated
May-10
Jun-10
Jul-10
Aug-10
Sep-10
Oct-10

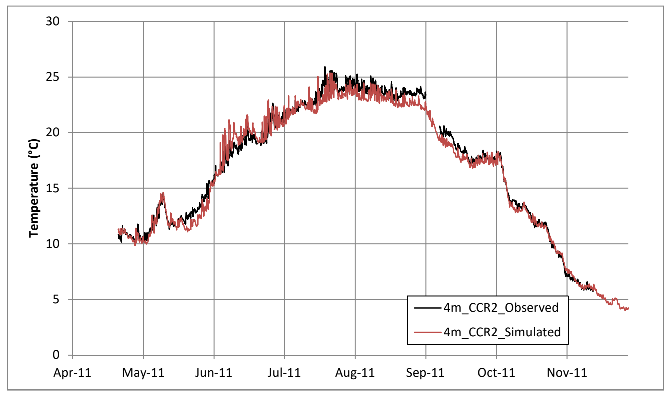

Temperature (°C)
6m_CCR2_Observed
6m_CCR2_Simulated
May-10
Jun-10
Jul-10
Aug-10
Sep-10
Oct-10

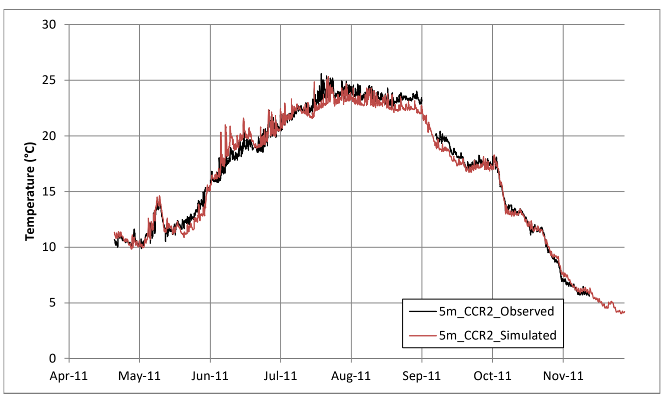

Temperature (°C)
7m_CCR2_Observed
7m_CCR2_Simulated
May-10
Jun-10
Jul-10
Aug-10
Sep-10
Oct-10

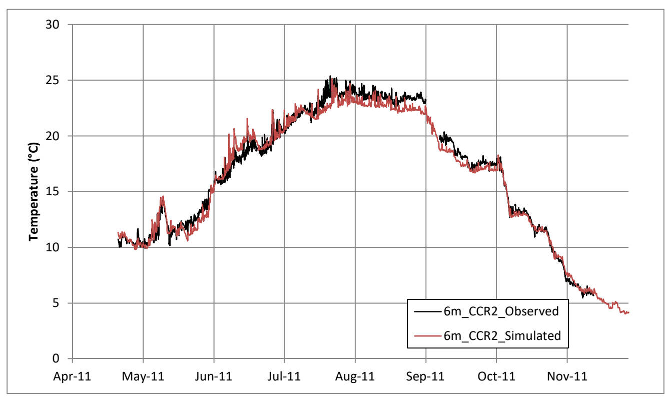

Temperature (°C)
0 5 10 15 20 25 30
Apr-11 May-11 Jun-11 Jul-11 Aug-11 Sep-11 Oct-11 Nov-11
1m_CCR2_Observed
1m_CCR2_Simulated


Temperature (°C)
0 5 10 15 20 25 30
Apr-11 May-11 Jun-11 Jul-11 Aug-11 Sep-11 Oct-11 Nov-11
2m_CCR2_Observed
2m_CCR2_Simulated

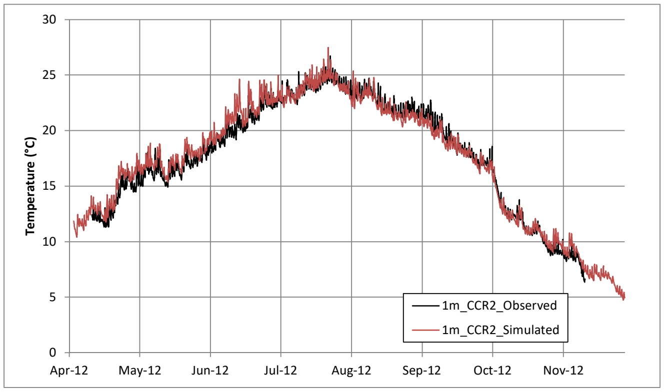

Temperature (°C)
0 5 10 15 20 25 30
Apr-11 May-11 Jun-11 Jul-11 Aug-11 Sep-11 Oct-11 Nov-11
3m_CCR2_Observed
3m_CCR2_Simulated

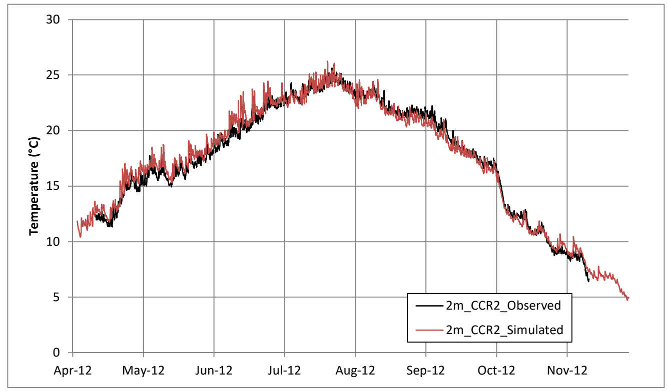

Temperature (°C)
0 5 10 15 20 25 30
Apr-11 May-11 Jun-11 Jul-11 Aug-11 Sep-11 Oct-11 Nov-11
4m_CCR2_Observed
4m_CCR2_Simulated

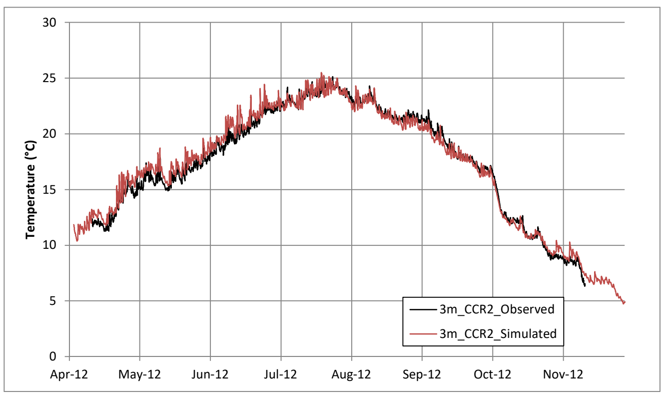

Temperature (°C)
0 5 10 15 20 25 30
Apr-11 May-11 Jun-11 Jul-11 Aug-11 Sep-11 Oct-11 Nov-11
5m_CCR2_Observed
5m_CCR2_Simulated

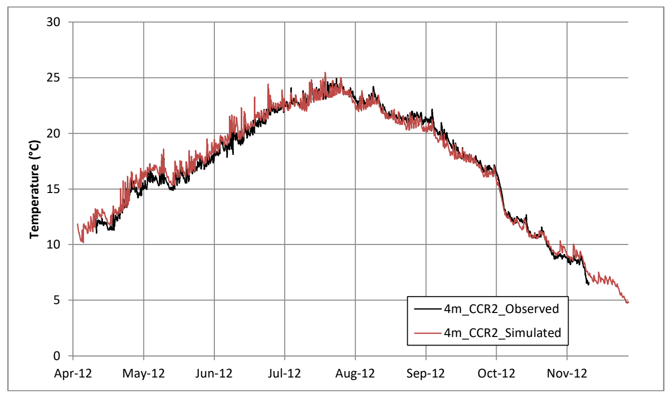

Temperature (°C)
0 5 10 15 20 25 30
Apr-11 May-11 Jun-11 Jul-11 Aug-11 Sep-11 Oct-11 Nov-11
6m_CCR2_Observed
6m_CCR2_Simulated

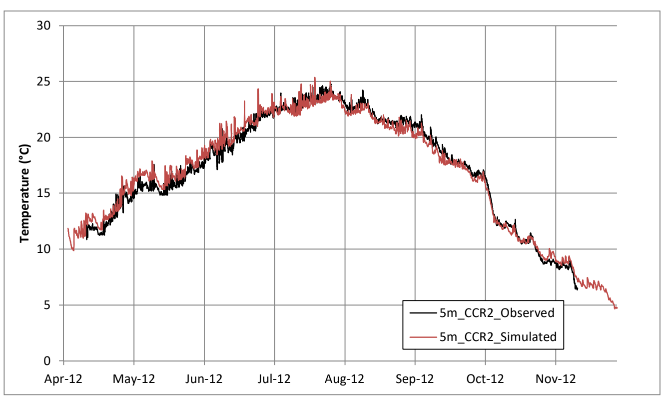

Temperature (°C)
0 5 10 15 20 25 30
Apr-11 May-11 Jun-11 Jul-11 Aug-11 Sep-11 Oct-11 Nov-11
7m_CCR2_Observed
7m_CCR2_Simulated

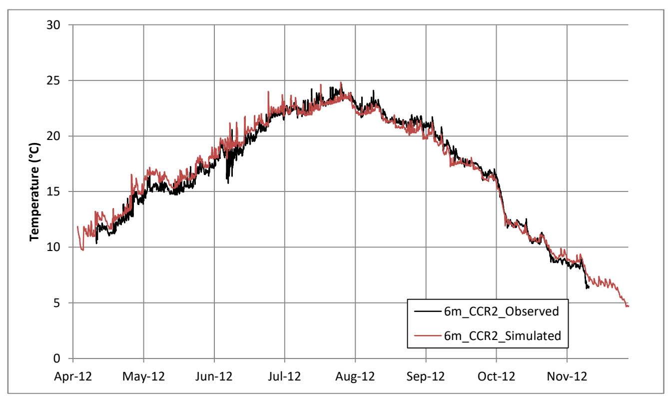

Temperature (°C)
0
5
10
15
20
25
30
Apr-12
May-12
Jun-12
Jul-12
Aug-12
Sep-12
Oct-12
Nov-12
1m_CCR2_Observed
1m_CCR2_Simulated

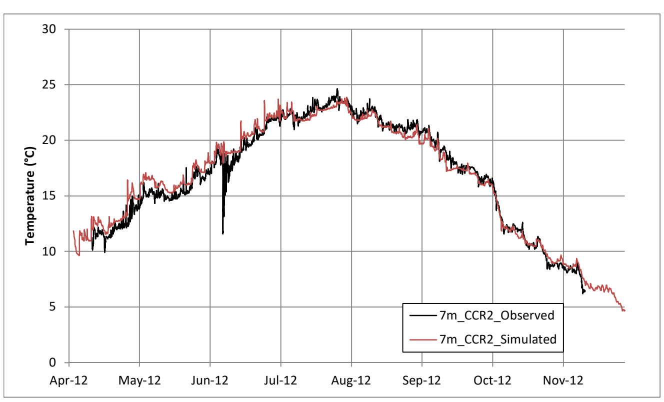

Temperature (°C)
0
5
10
15
20
25
30
Apr-12
May-12
Jun-12
Jul-12
Aug-12
Sep-12
Oct-12
Nov-12
2m_CCR2_Observed
2m_CCR2_Simulated

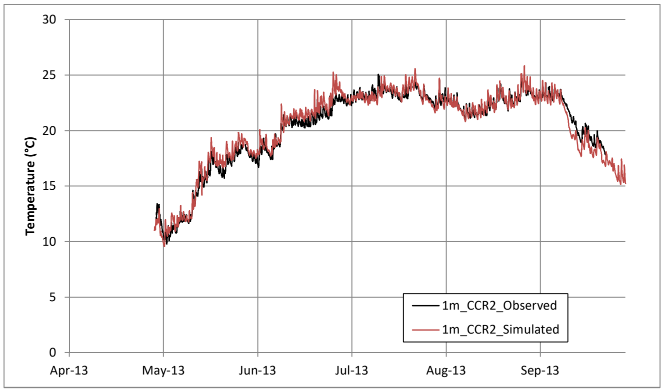

Temperature (°C)
0
5
10
15
20
25
30
Apr-12
May-12
Jun-12
Jul-12
Aug-12
Sep-12
Oct-12
Nov-12
3m_CCR2_Observed
3m_CCR2_Simulated

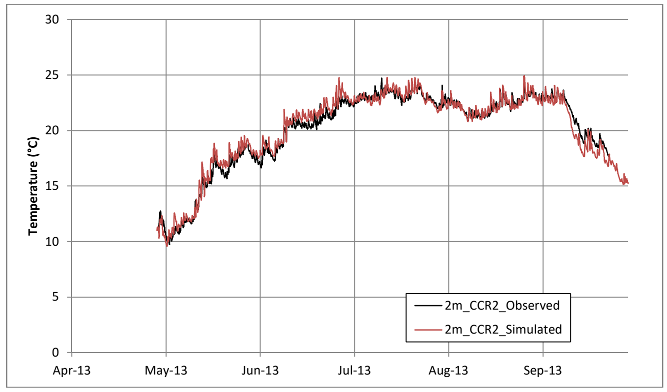

Temperature (°C)
0
5
10
15
20
25
30
Apr-12
May-12
Jun-12
Jul-12
Aug-12
Sep-12
Oct-12
Nov-12
4m_CCR2_Observed
4m_CCR2_Simulated

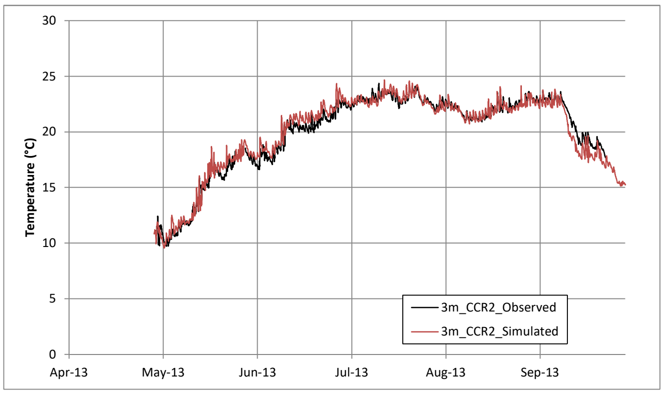

Temperature (°C)
0
5
10
15
20
25
30
Apr-12
May-12
Jun-12
Jul-12
Aug-12
Sep-12
Oct-12
Nov-12
5m_CCR2_Observed
5m_CCR2_Simulated

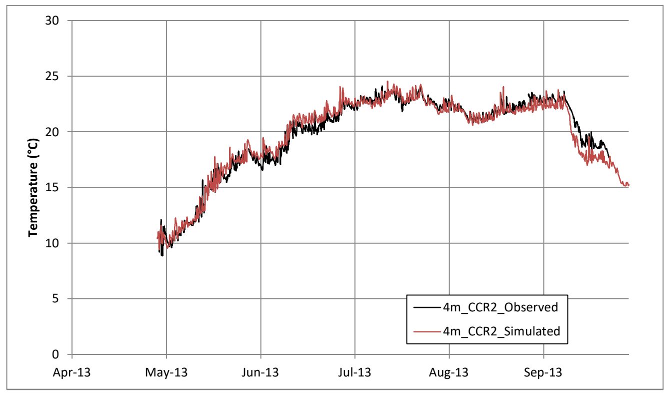

Temperature (°C)
0
5
10
15
20
25
30
Apr-12
May-12
Jun-12
Jul-12
Aug-12
Sep-12
Oct-12
Nov-12
6m_CCR2_Observed
6m_CCR2_Simulated

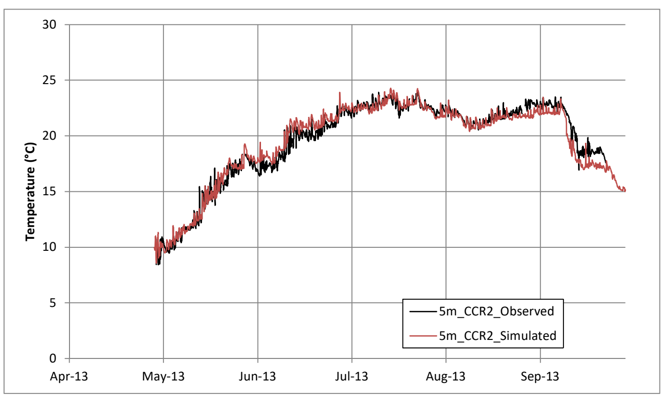

Temperature (°C)
0
5
10
15
20
25
30
Apr-12
May-12
Jun-12
Jul-12
Aug-12
Sep-12
Oct-12
Nov-12
7m_CCR2_Observed
7m_CCR2_Simulated

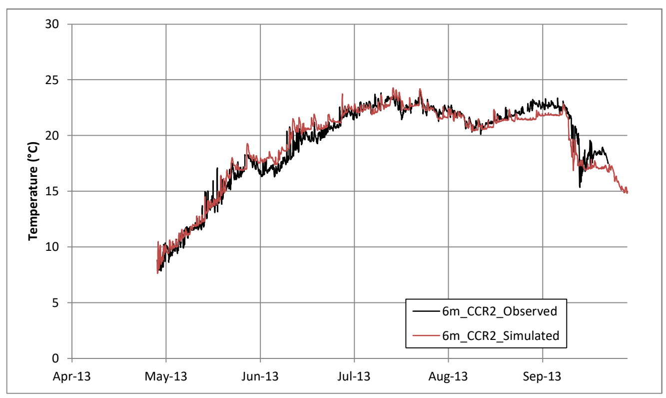

Temperature (°C)
1m_CCR2_Observed
1m_CCR2_Simulated
Apr-13
May-13
Jun-13
Jul-13
Aug-13
Sep-13

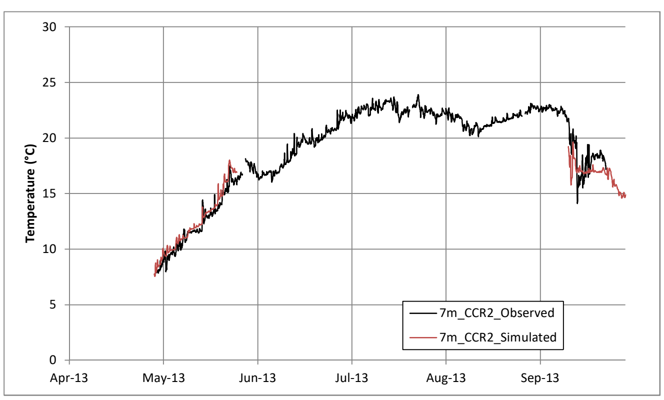

Temperature (°C)
2m_CCR2_Observed
2m_CCR2_Simulated
Apr-13
May-13
Jun-13
Jul-13
Aug-13
Sep-13

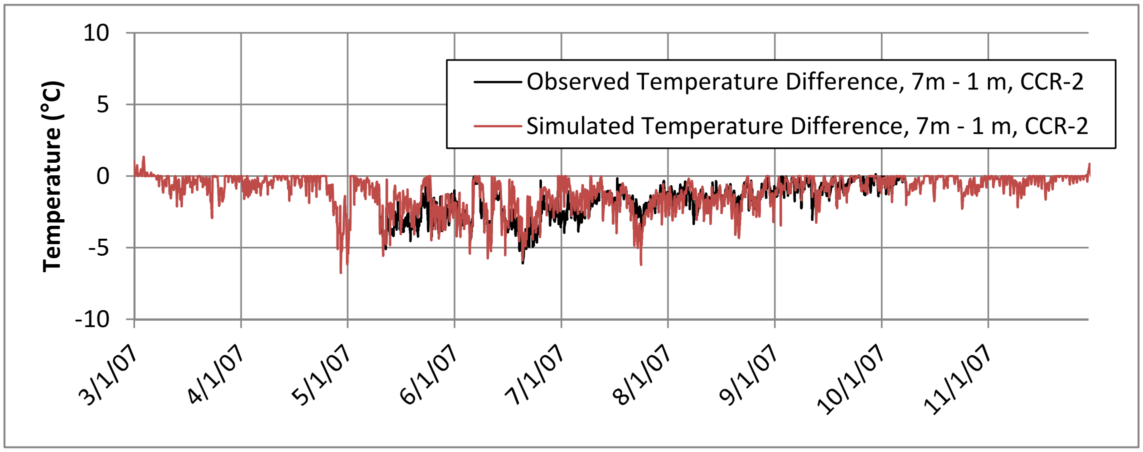

Temperature (°C)
3m_CCR2_Observed
3m_CCR2_Simulated
Apr-13
May-13
Jun-13
Jul-13
Aug-13
Sep-13

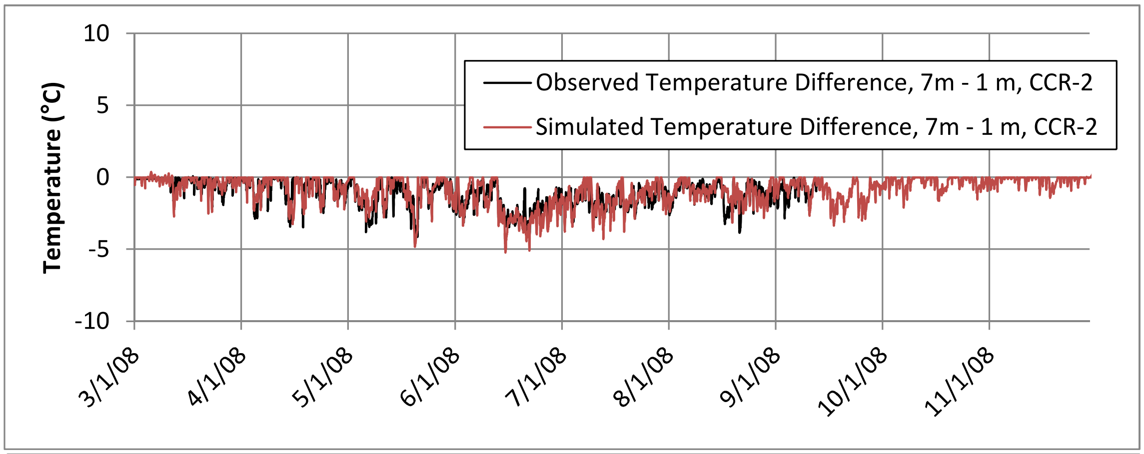

Temperature (°C)
4m_CCR2_Observed
4m_CCR2_Simulated
Apr-13
May-13
Jun-13
Jul-13
Aug-13
Sep-13

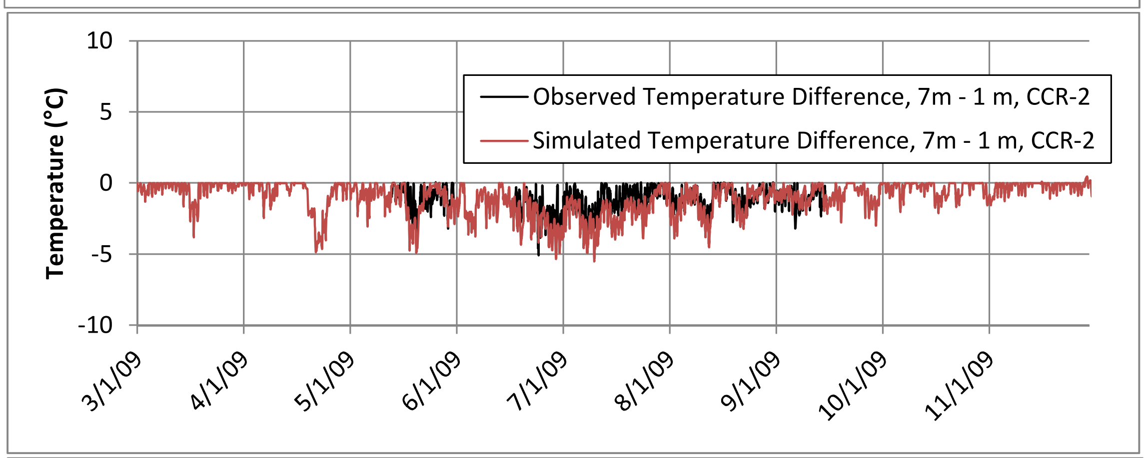

Temperature (°C)
5m_CCR2_Observed
5m_CCR2_Simulated
Apr-13
May-13
Jun-13
Jul-13
Aug-13
Sep-13

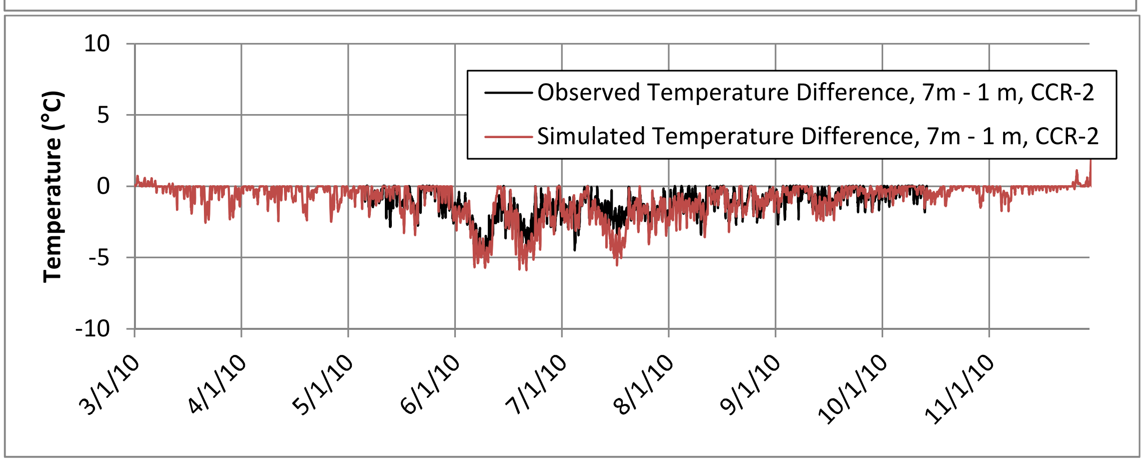

Temperature (°C)
6m_CCR2_Observed
6m_CCR2_Simulated
Apr-13
May-13
Jun-13
Jul-13
Aug-13
Sep-13

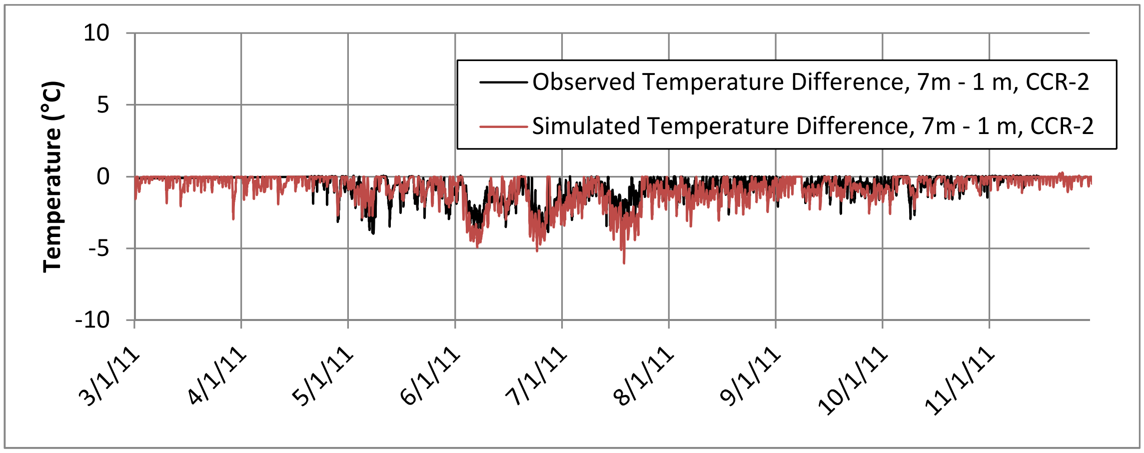

Temperature (°C)
7m_CCR2_Observed
7m_CCR2_Simulated
Apr-13
May-13
Jun-13
Jul-13
Aug-13
Sep-13

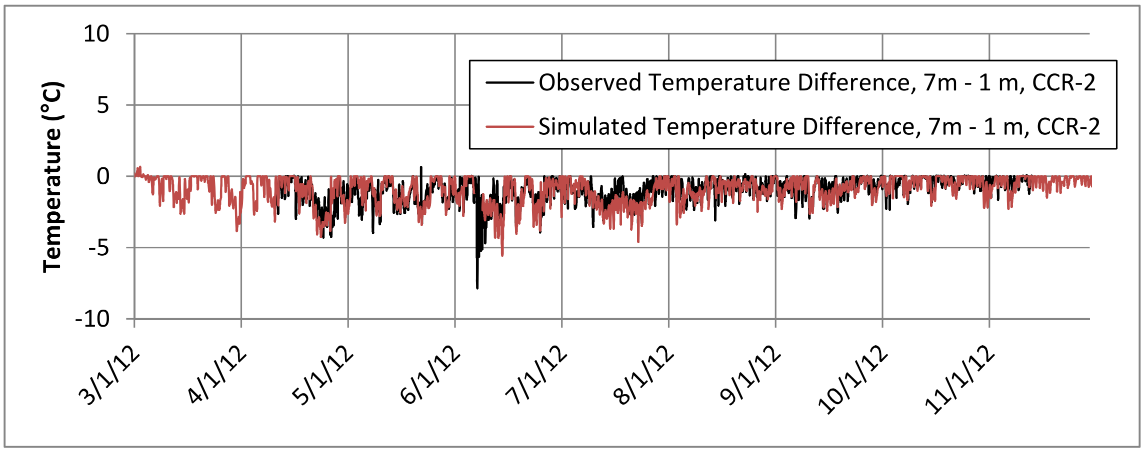

Observed Temperature Difference, 7m - 1 m, CCR-2
Simulated Temperature Difference, 7m - 1 m, CCR-2
Temperature (°C)
10
5
0
-5
-10
3/1/07
4/1/07
5/1/07
6/1/07
7/1/07
8/1/07
9/1/07
10/1/07
11/1/07

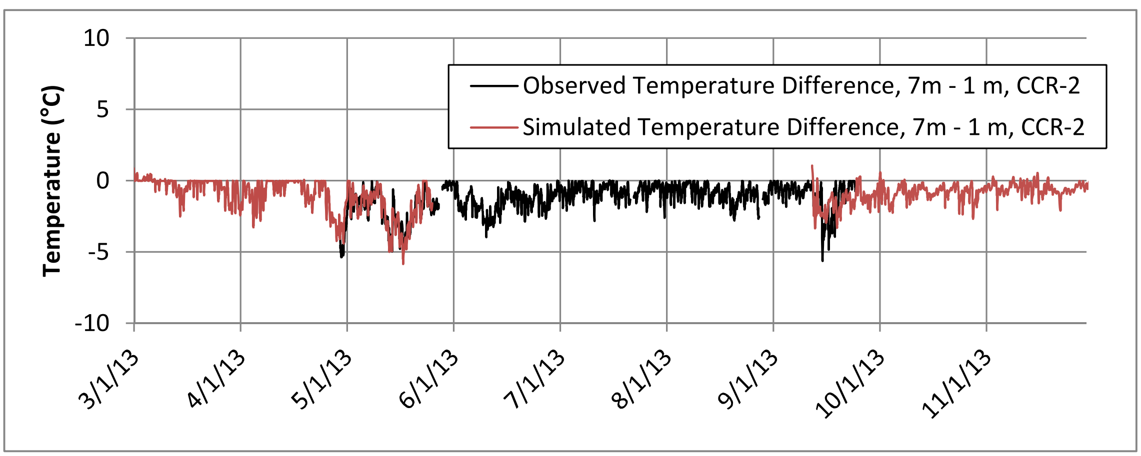

Observed Temperature Difference, 7m - 1 m, CCR-2
Simulated Temperature Difference, 7m - 1 m, CCR-2
Temperature (°C)
10
5
0
-5
-10
3/1/08
4/1/08
5/1/08
6/1/08
7/1/08
8/1/08
9/1/08
10/1/08
11/1/08


Observed Temperature Difference, 7m - 1 m, CCR-2
Simulated Temperature Difference, 7m - 1 m, CCR-2
Temperature (°C)
10
5
0
-5
-10
3/1/09
4/1/09
5/1/09
6/1/09
7/1/09
8/1/09
9/1/09
10/1/09
11/1/09

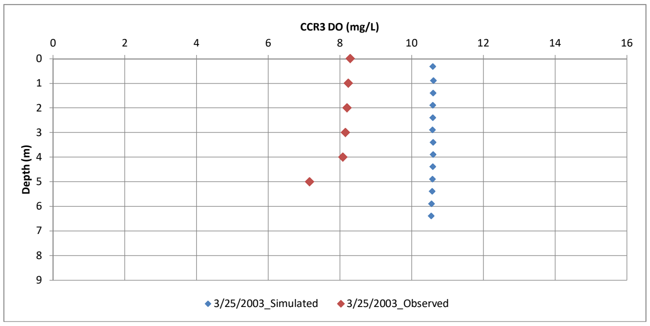

Observed Temperature Difference, 7m - 1 m, CCR-2
Simulated Temperature Difference, 7m - 1 m, CCR-2
Temperature (°C)
10
5
0
-5
-10
3/1/10
4/1/10
5/1/10
6/1/10
7/1/10
8/1/10
9/1/10
10/1/10
11/1/10

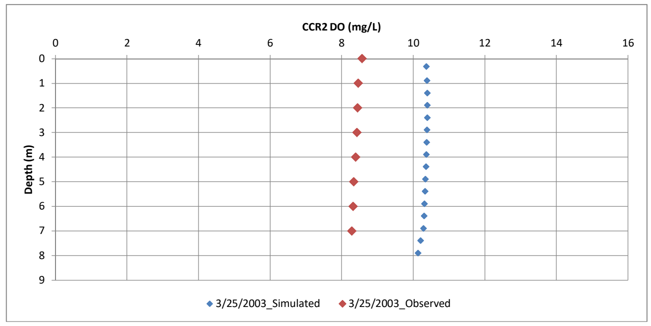

Temperature (°C)
Observed Temperature Difference, 7m - 1 m, CCR-2
Simulated Temperature Difference, 7m - 1 m, CCR-2
10
5
0
-5
-10
3/1/11
4/1/11
5/1/11
6/1/11
7/1/11
8/1/11
9/1/11
10/1/11
11/1/11

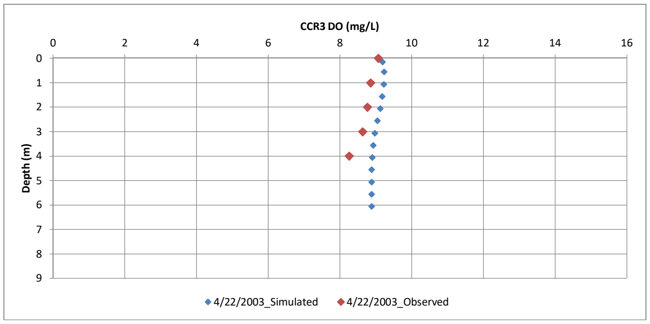

Temperature (°C)
Observed Temperature Difference, 7m - 1 m, CCR-2
Simulated Temperature Difference, 7m - 1 m, CCR-2
10
5
0
-5
-10
3/1/12
4/1/12
5/1/12
6/1/12
7/1/12
8/1/12
9/1/12
10/1/12
11/1/12

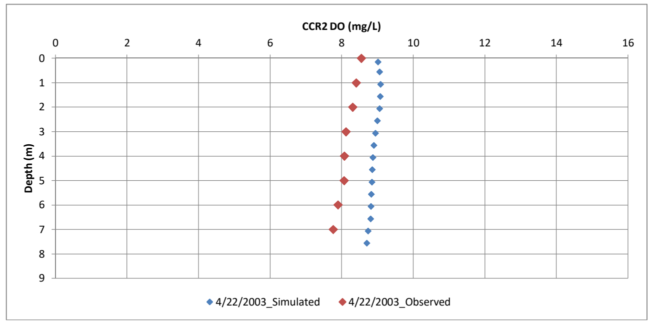

Temperature (°C)
Observed Temperature Difference, 7m - 1 m, CCR-2
Simulated Temperature Difference, 7m - 1 m, CCR-2
10
5
0
-5
-10
3/1/13
4/1/13
5/1/13
6/1/13
7/1/13
8/1/13
9/1/13
10/1/13
11/1/13

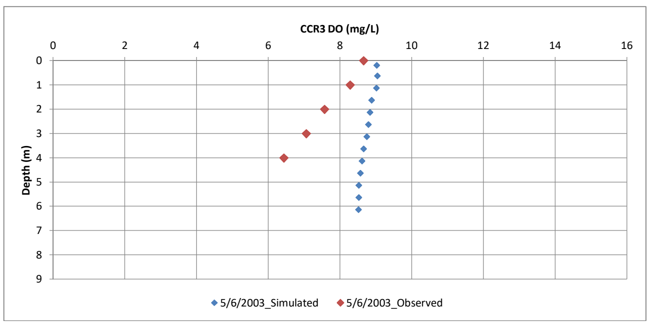
Attachment C: Dissolved Oxygen Profiles: Observed and Simulated Results

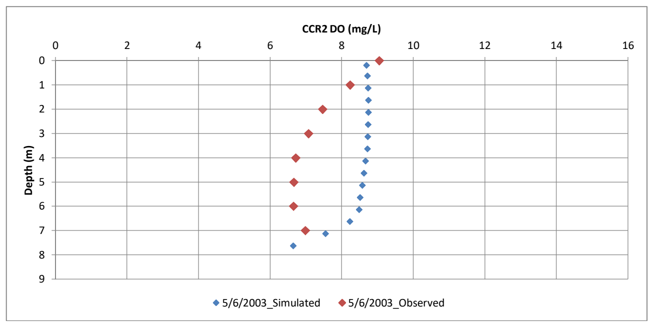

CCR3 DO (mg/L)
Depth (m)
3/25/2003_Simulated
3/25/2003_Observed

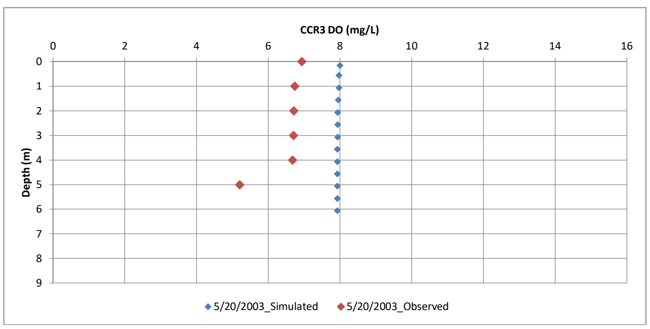

CCR2 DO (mg/L)
Depth (m)
3/25/2003_Simulated
3/25/2003_Observed

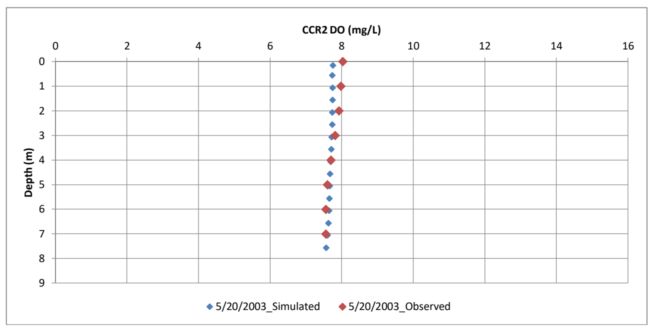

CCR3 DO (mg/L)
Depth (m)
4/22/2003_Simulated
4/22/2003_Observed

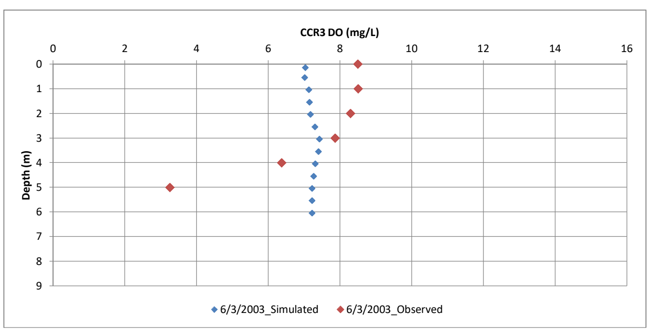

CCR2 DO (mg/L)
Depth (m)
4/22/2003_Simulated
4/22/2003_Observed

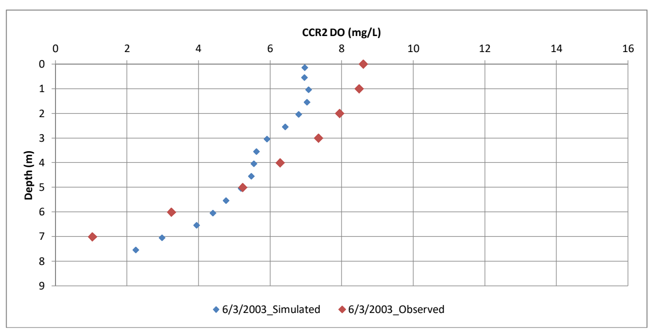

CCR3 DO (mg/L)
Depth (m)
5/6/2003_Simulated
5/6/2003_Observed

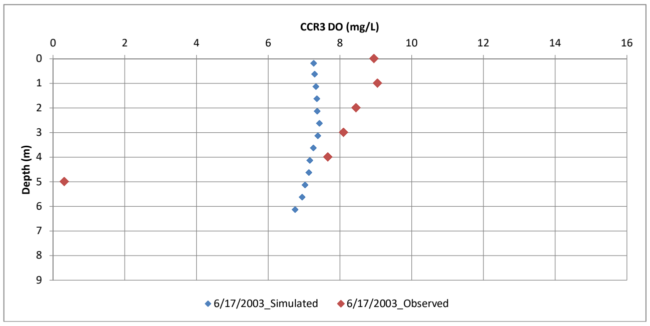

CCR2 DO (mg/L)
Depth (m)
5/6/2003_Simulated
5/6/2003_Observed

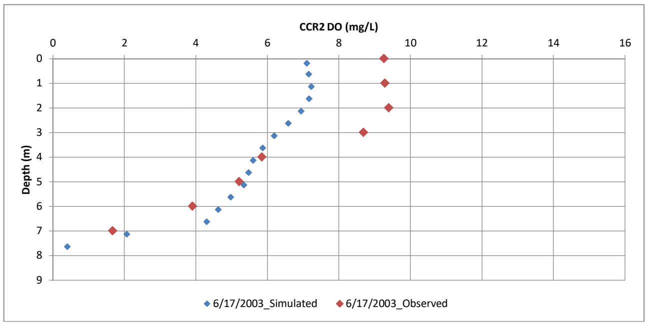

CCR3 DO (mg/L)
Depth (m)
5/20/2003_Simulated
5/20/2003_Observed

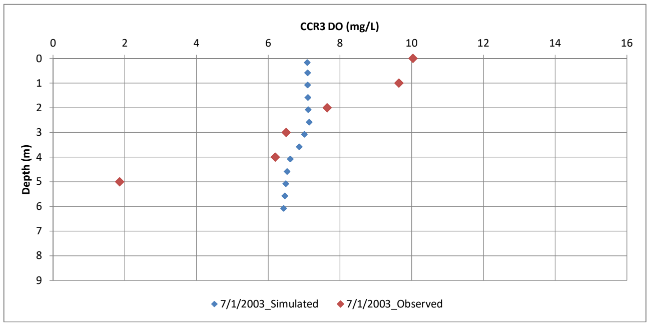

CCR2 DO (mg/L)
Depth (m)
5/20/2003_Simulated
5/20/2003_Observed

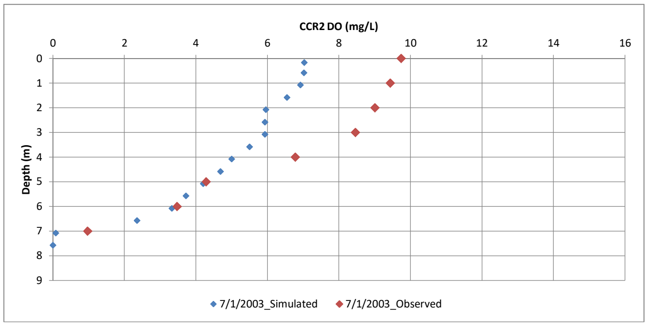

CCR3 DO (mg/L)
Depth (m)
6/3/2003_Simulated
6/3/2003_Observed

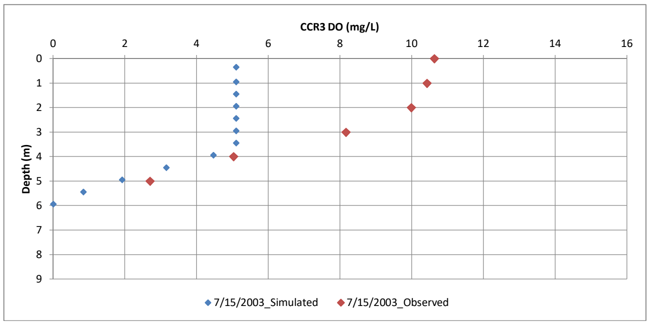

CCR2 DO (mg/L)
Depth (m)
6/3/2003_Simulated
6/3/2003_Observed

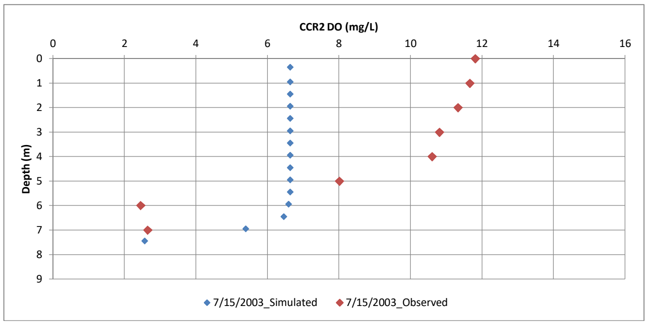

CCR3 DO (mg/L)
Depth (m)
6/17/2003_Simulated
6/17/2003_Observed

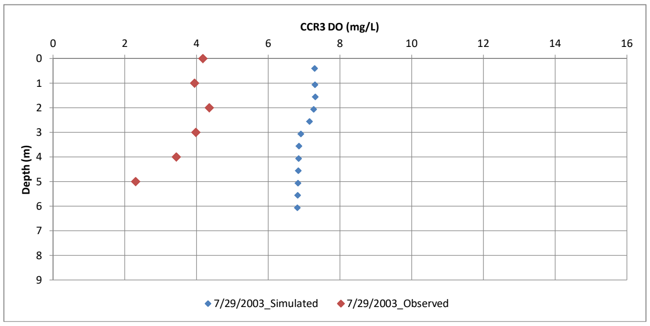

CCR2 DO (mg/L)
Depth (m)
6/17/2003_Simulated
6/17/2003_Observed

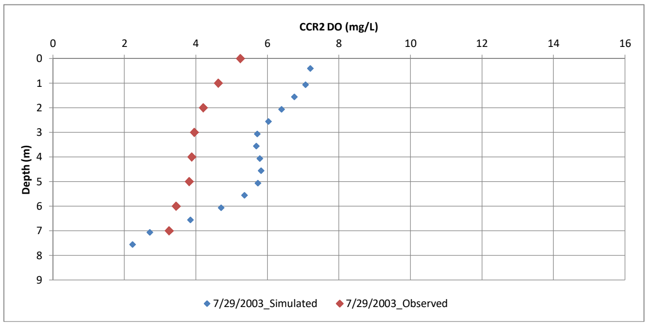

CCR3 DO (mg/L)
Depth (m)
7/1/2003_Simulated
7/1/2003_Observed

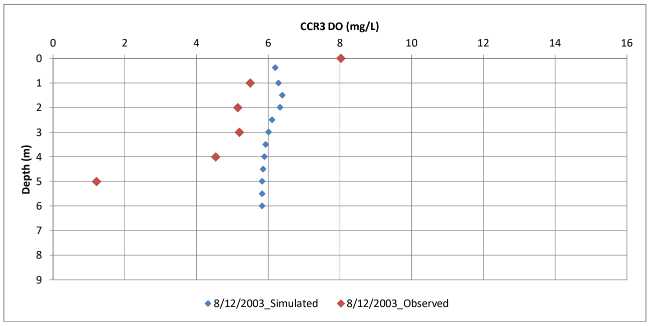

CCR2 DO (mg/L)
Depth (m)
7/1/2003_Simulated
7/1/2003_Observed

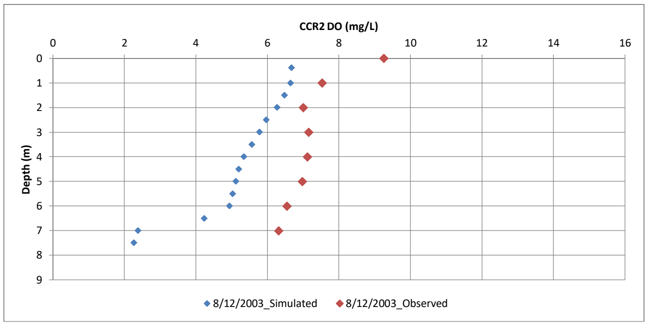

CCR3 DO (mg/L)
Depth (m)
7/15/2003_Simulated
7/15/2003_Observed

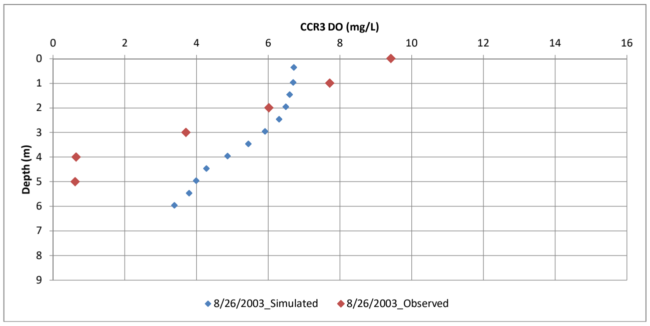

CCR2 DO (mg/L)
Depth (m)
7/15/2003_Simulated
7/15/2003_Observed

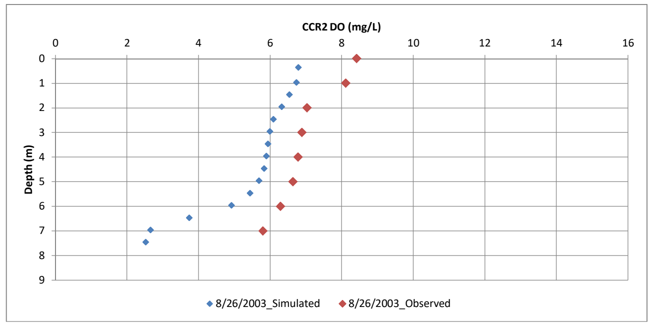

CCR3 DO (mg/L)
Depth (m)
7/29/2003_Simulated
7/29/2003_Observed

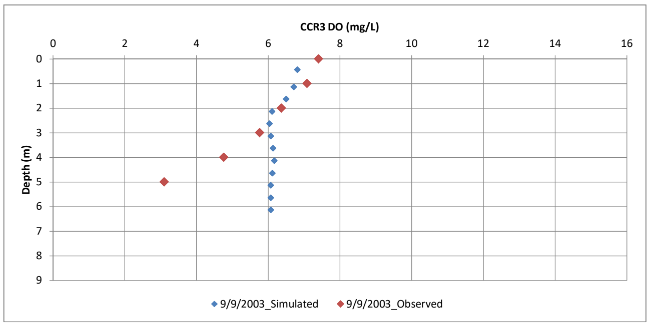

CCR2 DO (mg/L)
Depth (m)
7/29/2003_Simulated
7/29/2003_Observed

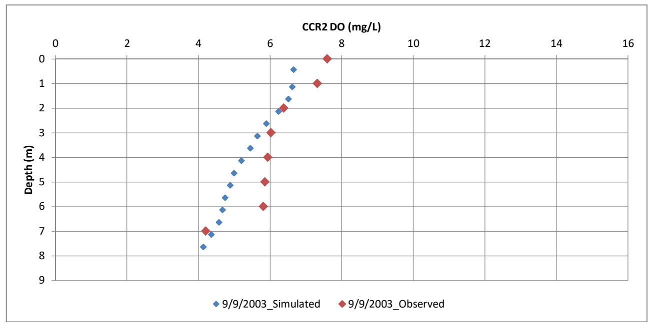

CCR3 DO (mg/L)
Depth (m)
8/12/2003_Simulated
8/12/2003_Observed

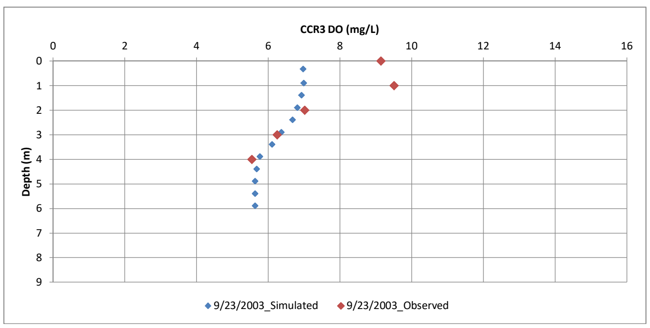

CCR2 DO (mg/L)
Depth (m)
8/12/2003_Simulated
8/12/2003_Observed

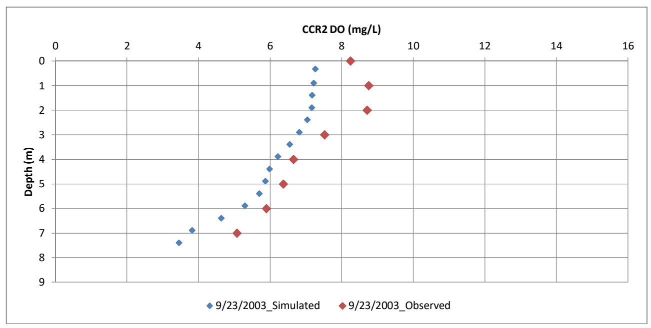

CCR3 DO (mg/L)
Depth (m)
8/26/2003_Simulated
8/26/2003_Observed

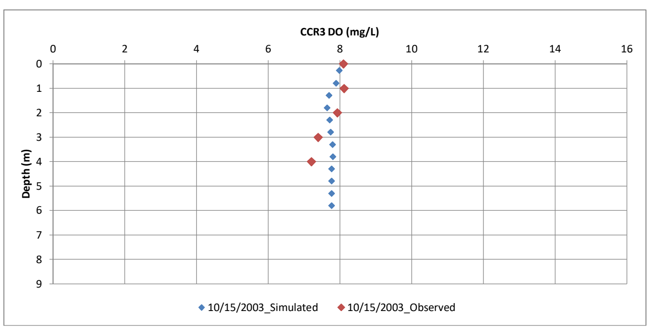

CCR2 DO (mg/L)
Depth (m)
8/26/2003_Simulated
8/26/2003_Observed

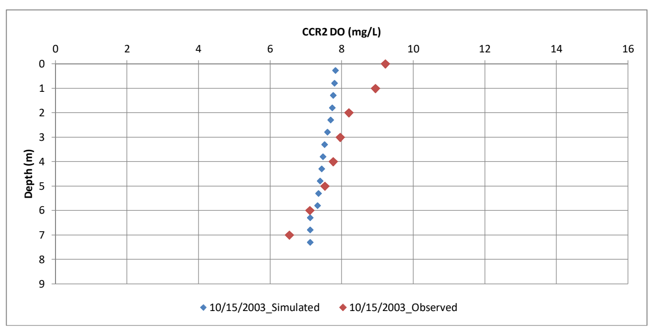

CCR3 DO (mg/L)
Depth (m)
9/9/2003_Simulated
9/9/2003_Observed

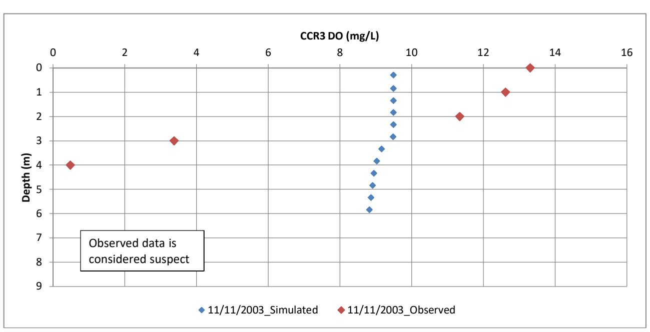

CCR2 DO (mg/L)
Depth (m)
9/9/2003_Simulated
9/9/2003_Observed

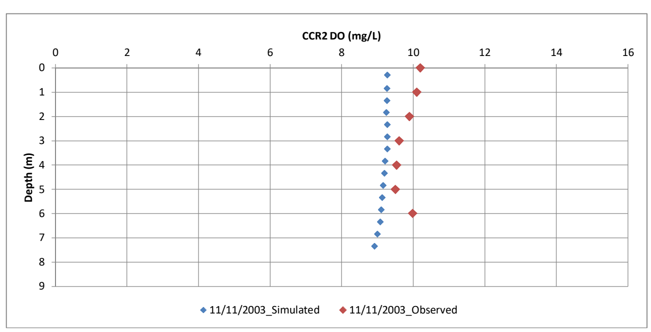

CCR3 DO (mg/L)
Depth (m)
9/23/2003_Simulated
9/23/2003_Observed

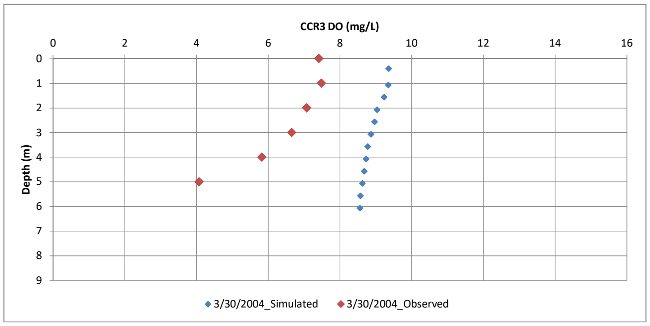

CCR2 DO (mg/L)
Depth (m)
9/23/2003_Simulated
9/23/2003_Observed

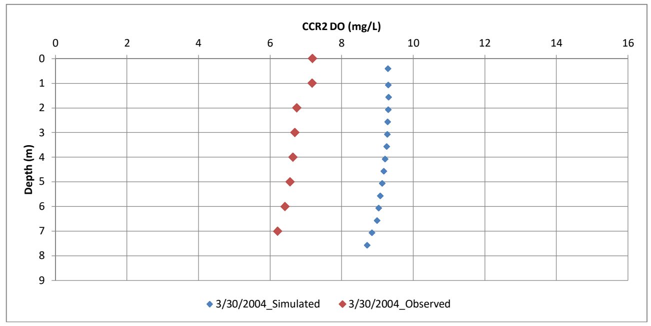

CCR3 DO (mg/L)
Depth (m)
10/15/2003_Simulated
10/15/2003_Observed

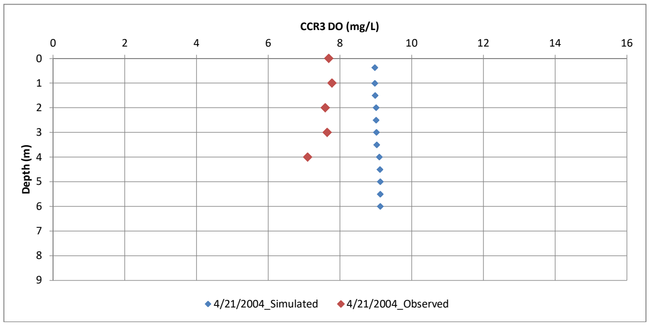

CCR2 DO (mg/L)
Depth (m)
10/15/2003_Simulated
10/15/2003_Observed

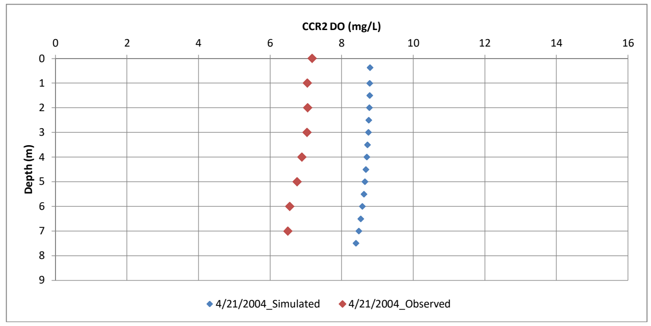

CCR3 DO (mg/L)
Depth (m)
Observed data is considered suspect
11/11/2003_Simulated
11/11/2003_Observed

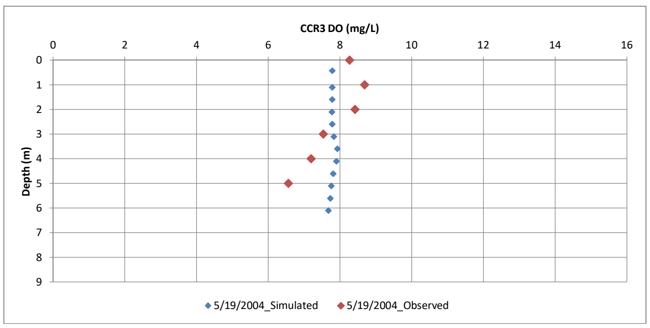

CCR2 DO (mg/L)
Depth (m)
11/11/2003_Simulated
11/11/2003_Observed

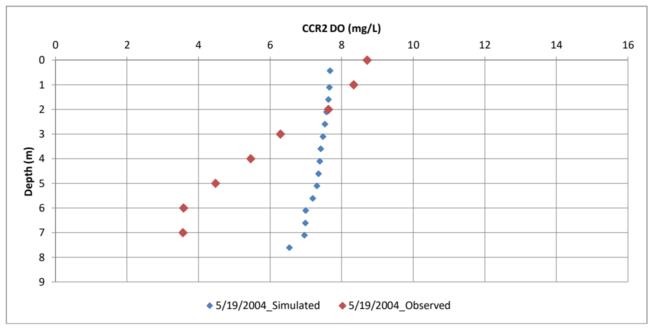

CCR3 DO (mg/L)
Depth (m)
3/30/2004_Simulated
3/30/2004_Observed

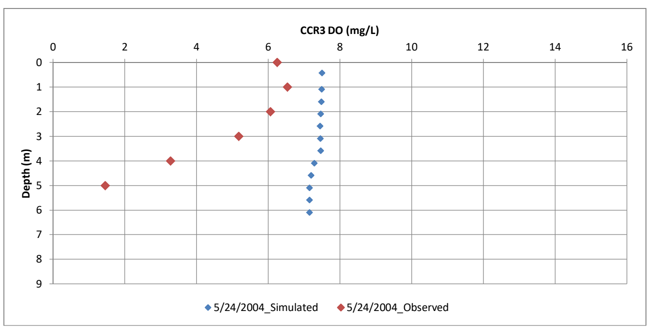

CCR2 DO (mg/L)
Depth (m)
3/30/2004_Simulated
3/30/2004_Observed

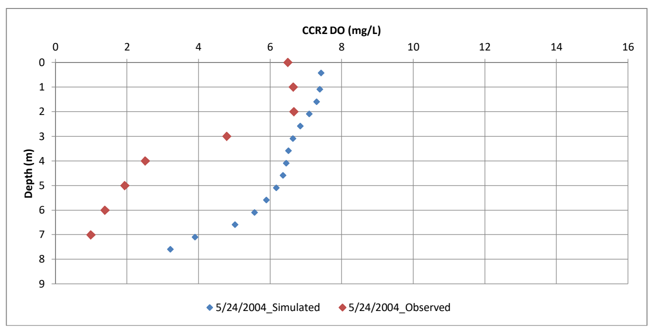

CCR3 DO (mg/L)
Depth (m)
4/21/2004_Simulated
4/21/2004_Observed

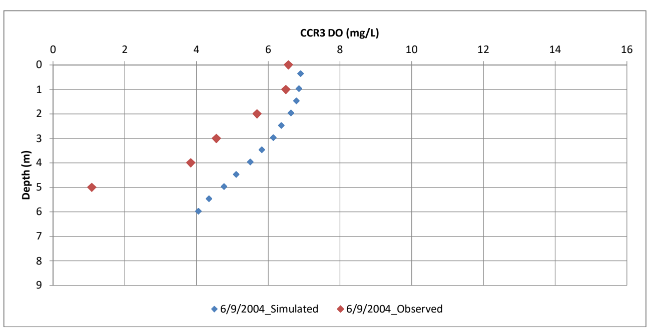

CCR2 DO (mg/L)
Depth (m)
4/21/2004_Simulated
4/21/2004_Observed

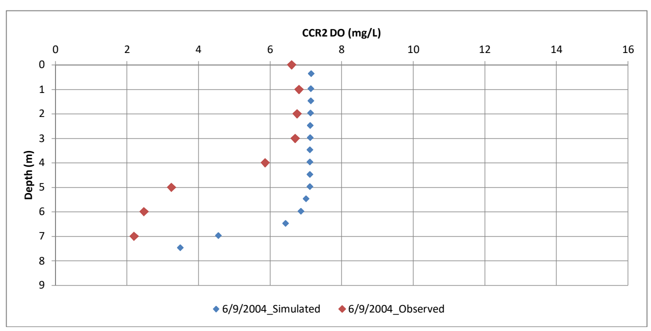

CCR3 DO (mg/L)
Depth (m)
5/19/2004_Simulated
5/19/2004_Observed

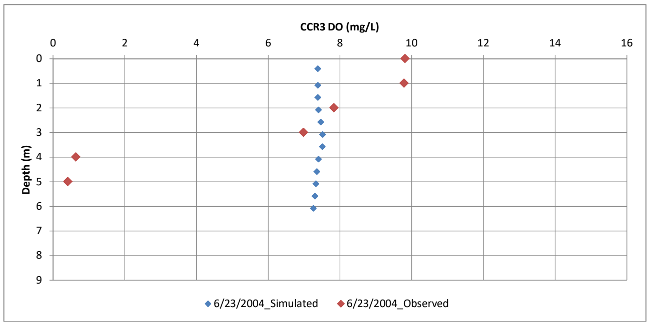

CCR2 DO (mg/L)
Depth (m)
5/19/2004_Simulated
5/19/2004_Observed

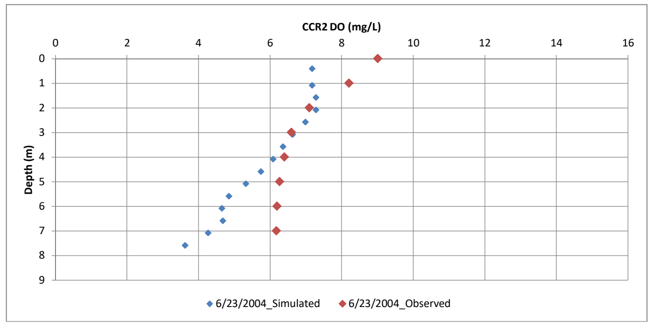

CCR3 DO (mg/L)
Depth (m)
5/24/2004_Simulated
5/24/2004_Observed

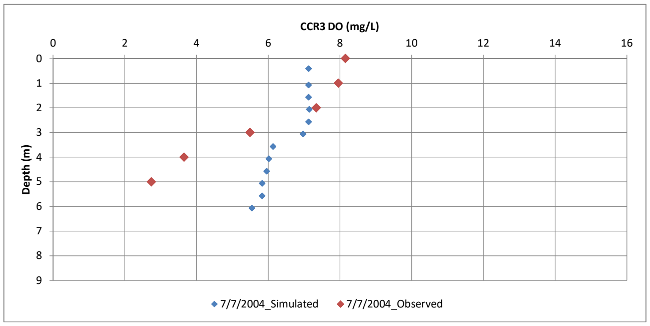

CCR2 DO (mg/L)
Depth (m)
5/24/2004_Simulated
5/24/2004_Observed

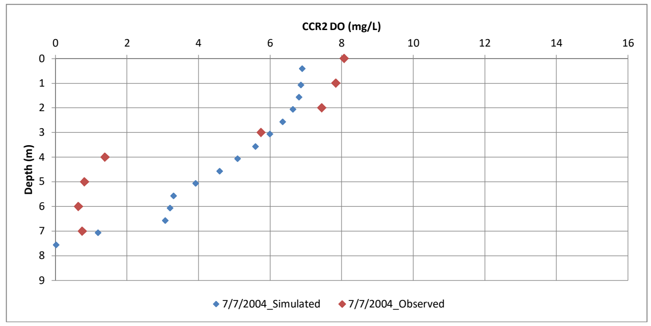

CCR3 DO (mg/L)
Depth (m)
6/9/2004_Simulated
6/9/2004_Observed

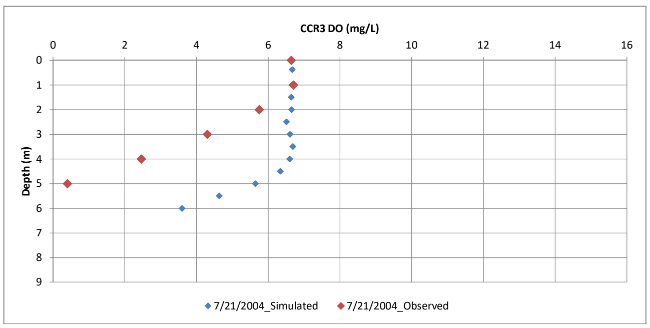

CCR2 DO (mg/L)
Depth (m)
6/9/2004_Simulated
6/9/2004_Observed

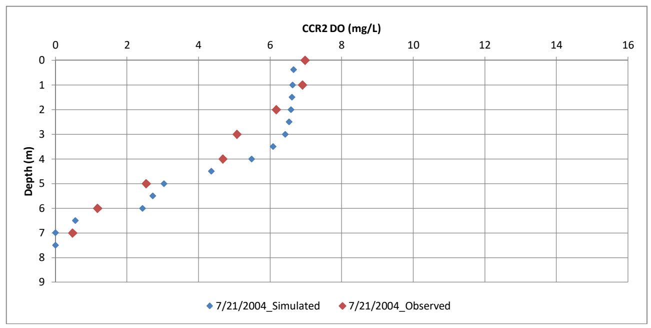

CCR3 DO (mg/L)
Depth (m)
6/23/2004_Simulated
6/23/2004_Observed

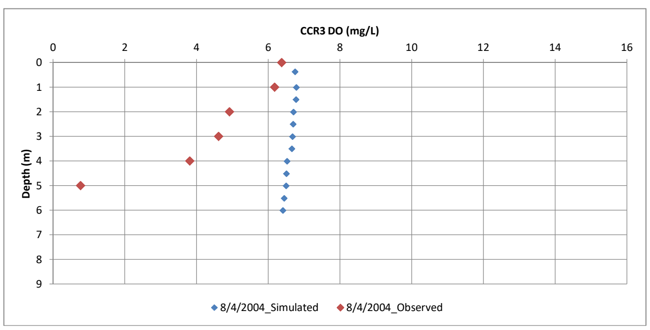

CCR2 DO (mg/L)
Depth (m)
6/23/2004_Simulated
6/23/2004_Observed

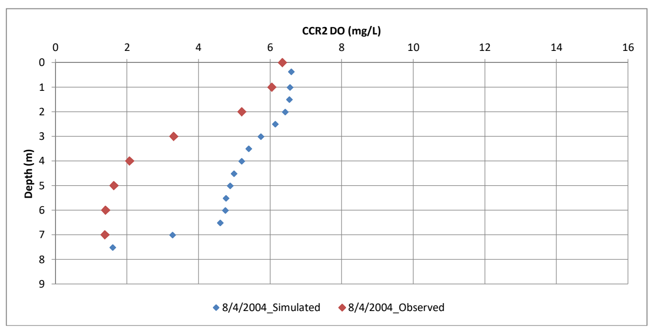

CCR3 DO (mg/L)
Depth (m)
7/7/2004_Simulated
7/7/2004_Observed

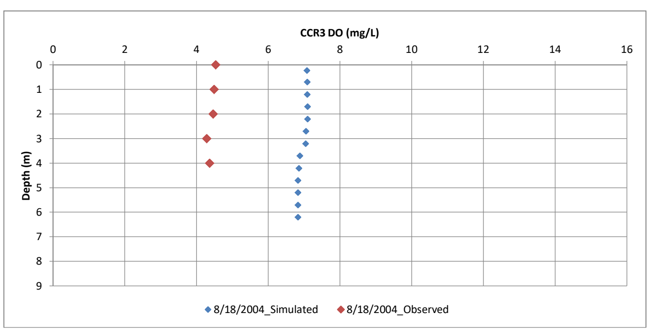

CCR2 DO (mg/L)
Depth (m)
7/7/2004_Simulated
7/7/2004_Observed

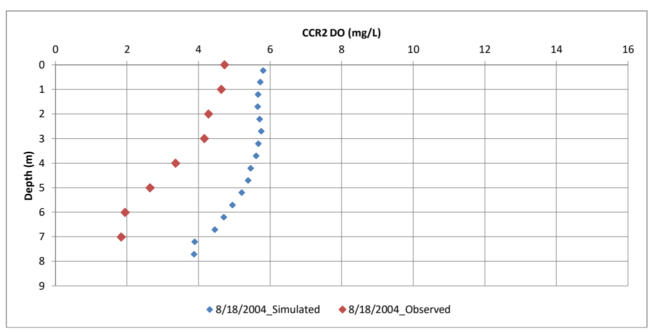

CCR3 DO (mg/L)
Depth (m)
7/21/2004_Simulated
7/21/2004_Observed

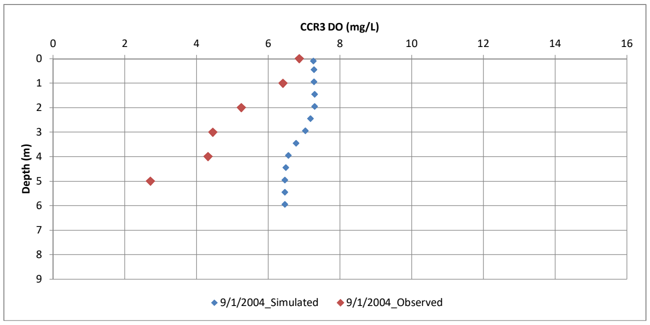

CCR2 DO (mg/L)
Depth (m)
7/21/2004_Simulated
7/21/2004_Observed

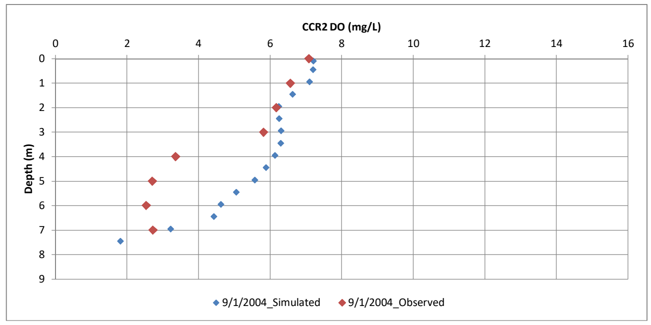

CCR3 DO (mg/L)
Depth (m)
8/4/2004_Simulated
8/4/2004_Observed

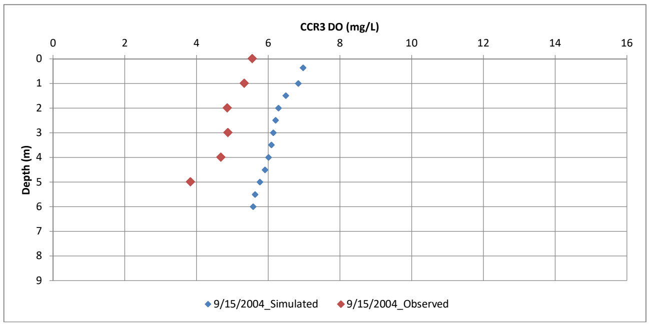

CCR2 DO (mg/L)
Depth (m)
8/4/2004_Simulated
8/4/2004_Observed

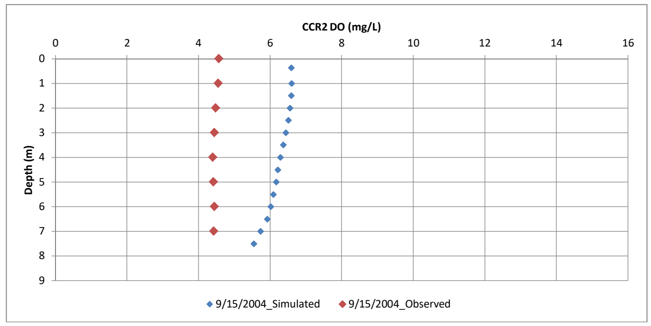

CCR3 DO (mg/L)
Depth (m)
8/18/2004_Simulated
8/18/2004_Observed

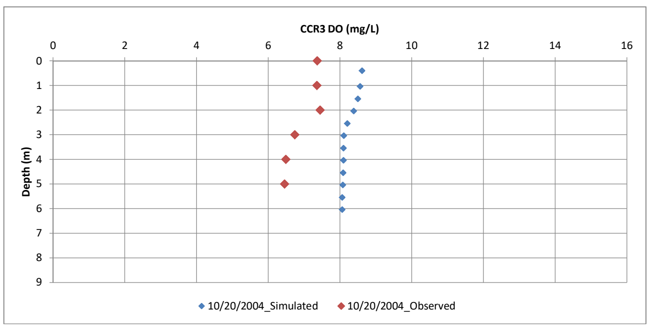

CCR2 DO (mg/L)
Depth (m)
8/18/2004_Simulated
8/18/2004_Observed

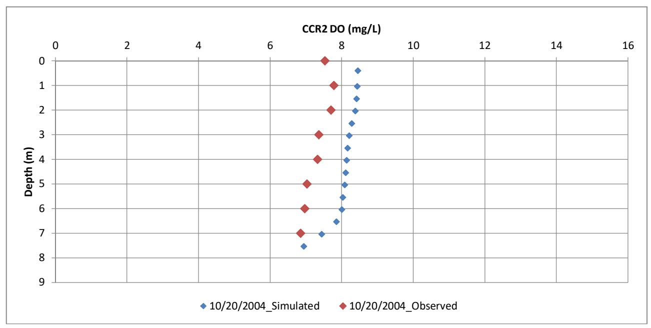

CCR3 DO (mg/L)
Depth (m)
9/1/2004_Simulated
9/1/2004_Observed

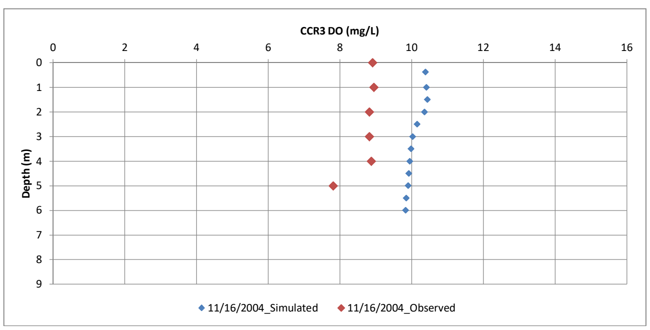

CCR2 DO (mg/L)
Depth (m)
9/1/2004_Simulated
9/1/2004_Observed

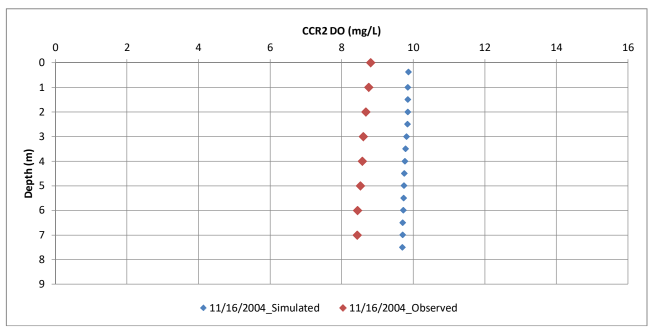

CCR3 DO (mg/L)
Depth (m)
9/15/2004_Simulated
9/15/2004_Observed

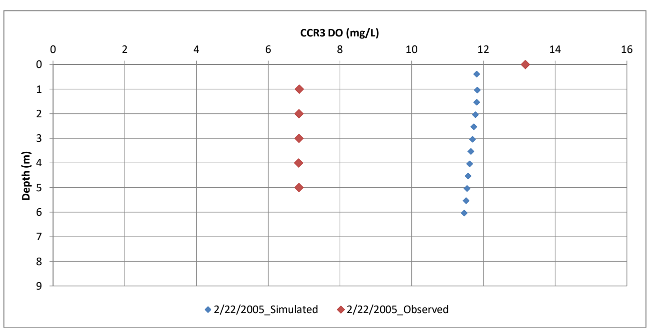

CCR2 DO (mg/L)
Depth (m)
9/15/2004_Simulated
9/15/2004_Observed

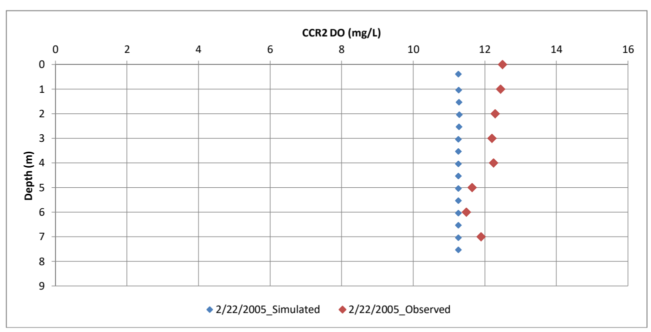

CCR3 DO (mg/L)
Depth (m)
10/20/2004_Simulated
10/20/2004_Observed

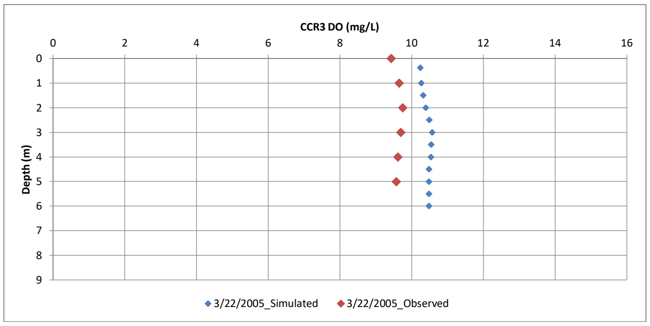

CCR2 DO (mg/L)
Depth (m)
10/20/2004_Simulated
10/20/2004_Observed

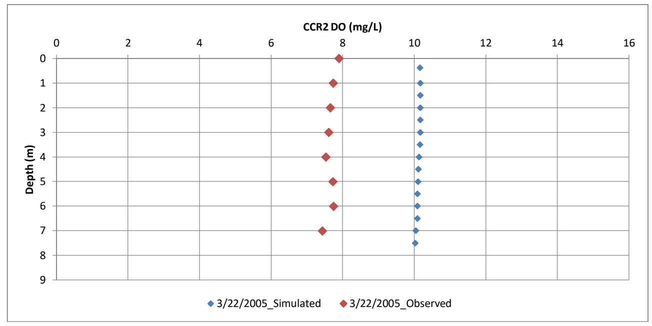

CCR3 DO (mg/L)
Depth (m)
11/16/2004_Simulated
11/16/2004_Observed

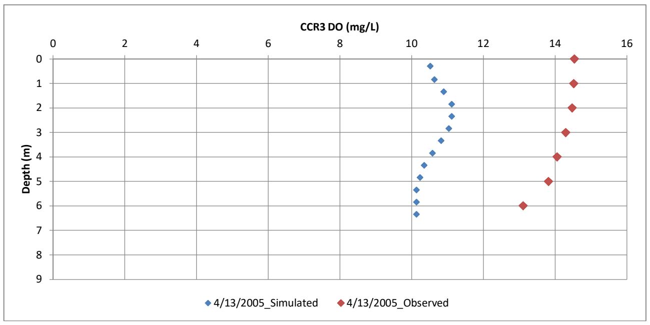

CCR2 DO (mg/L)
Depth (m)
11/16/2004_Simulated
11/16/2004_Observed

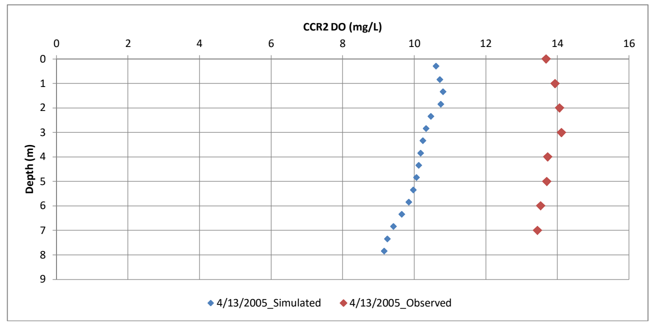

CCR3 DO (mg/L)
Depth (m)
2/22/2005_Simulated
2/22/2005_Observed

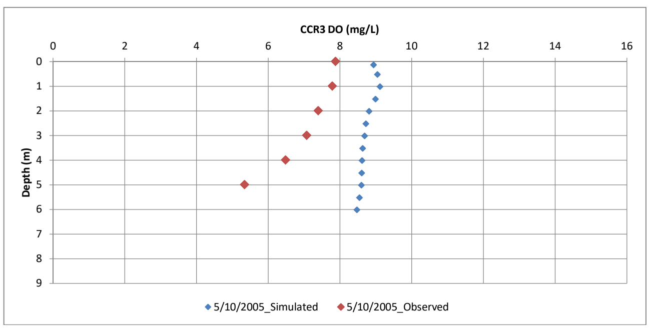

CCR2 DO (mg/L)
Depth (m)
2/22/2005_Simulated
2/22/2005_Observed

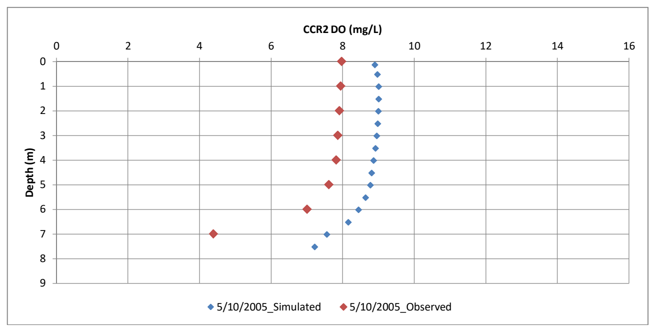

CCR3 DO (mg/L)
Depth (m)
3/22/2005_Simulated
3/22/2005_Observed

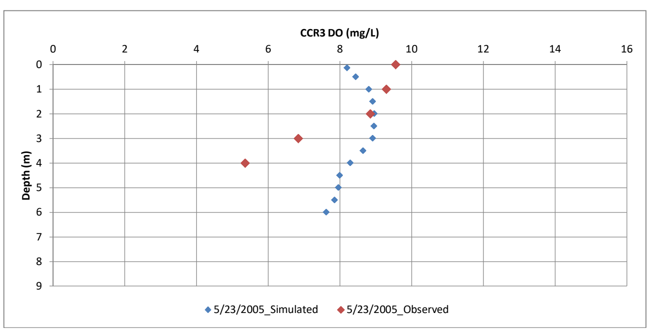

CCR2 DO (mg/L)
Depth (m)
3/22/2005_Simulated
3/22/2005_Observed

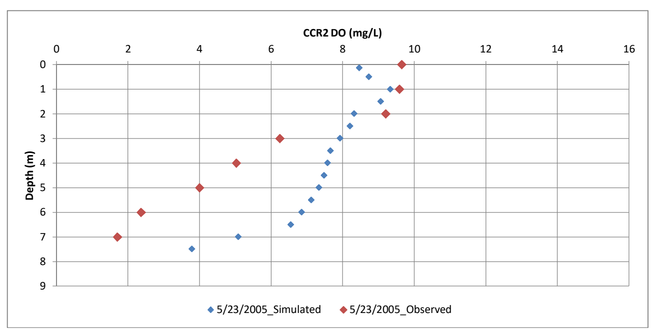

CCR3 DO (mg/L)
Depth (m)
4/13/2005_Simulated
4/13/2005_Observed

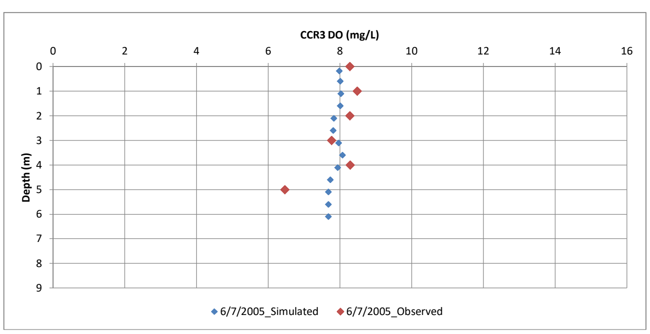

CCR2 DO (mg/L)
Depth (m)
4/13/2005_Simulated
4/13/2005_Observed

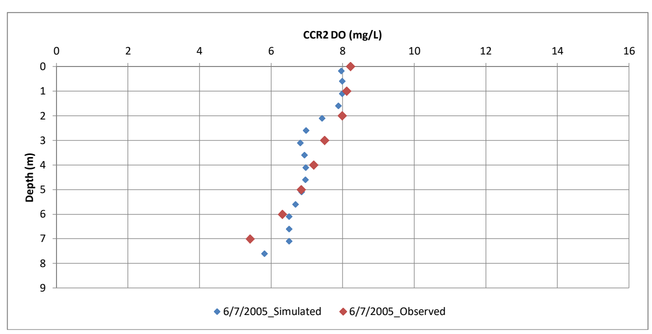

CCR3 DO (mg/L)
Depth (m)
5/10/2005_Simulated
5/10/2005_Observed

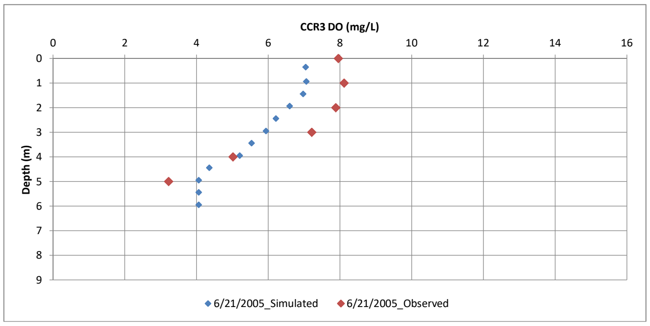

CCR2 DO (mg/L)
Depth (m)
5/10/2005_Simulated
5/10/2005_Observed

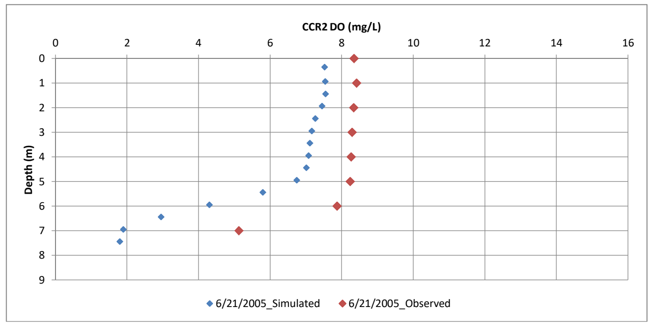

CCR3 DO (mg/L)
Depth (m)
5/23/2005_Simulated
5/23/2005_Observed

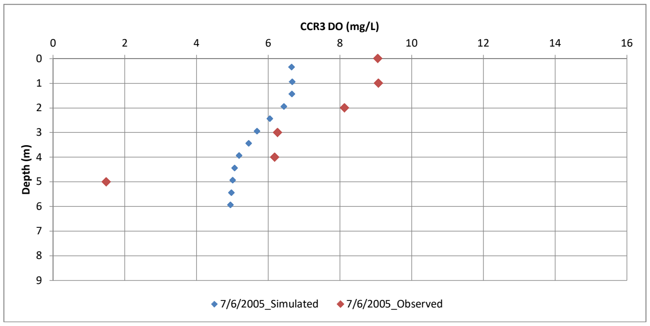

CCR2 DO (mg/L)
Depth (m)
5/23/2005_Simulated
5/23/2005_Observed

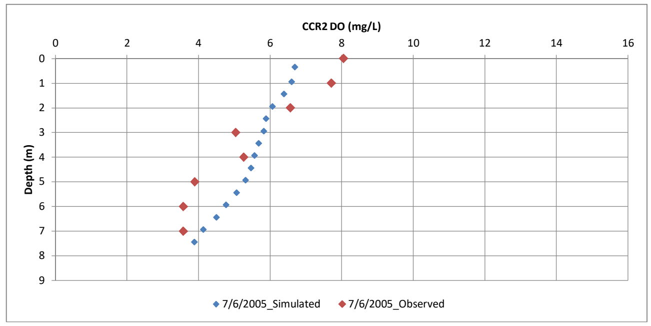

CCR3 DO (mg/L)
Depth (m)
6/7/2005_Simulated
6/7/2005_Observed

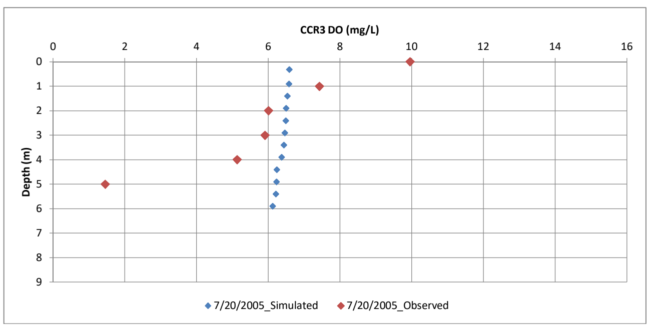

CCR2 DO (mg/L)
Depth (m)
6/7/2005_Simulated
6/7/2005_Observed

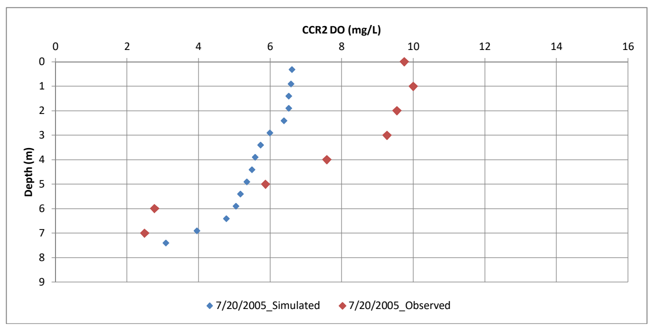

CCR3 DO (mg/L)
Depth (m)
6/21/2005_Simulated
6/21/2005_Observed

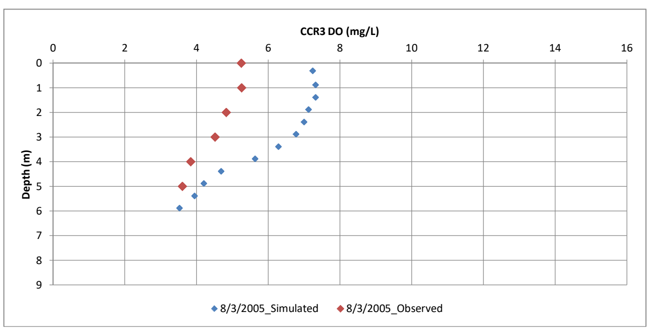

CCR2 DO (mg/L)
Depth (m)
6/21/2005_Simulated
6/21/2005_Observed

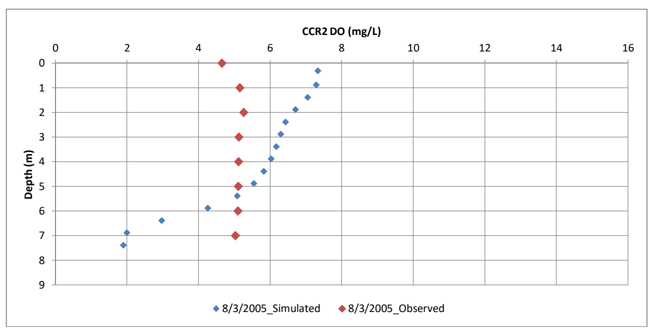

CCR3 DO (mg/L)
Depth (m)
7/6/2005_Simulated
7/6/2005_Observed

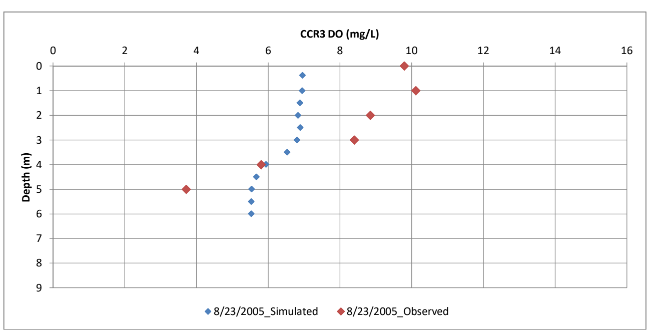

CCR2 DO (mg/L)
Depth (m)
7/6/2005_Simulated
7/6/2005_Observed

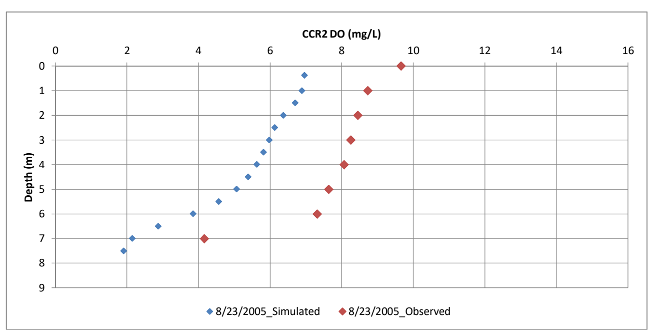

CCR3 DO (mg/L)
Depth (m)
7/20/2005_Simulated
7/20/2005_Observed

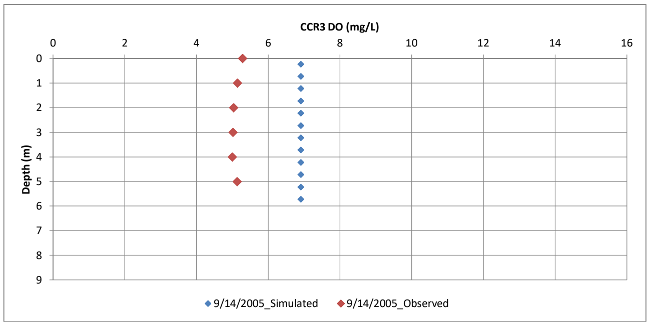

CCR2 DO (mg/L)
Depth (m)
7/20/2005_Simulated
7/20/2005_Observed

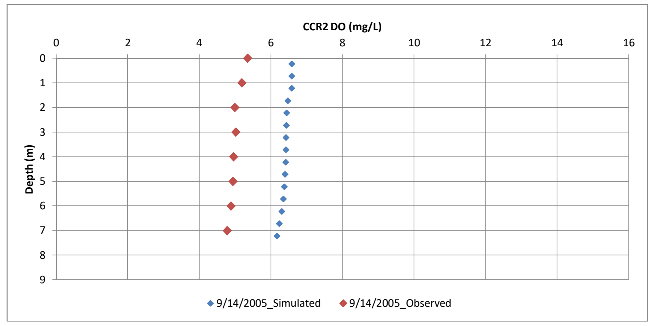

CCR3 DO (mg/L)
Depth (m)
8/3/2005_Simulated
8/3/2005_Observed

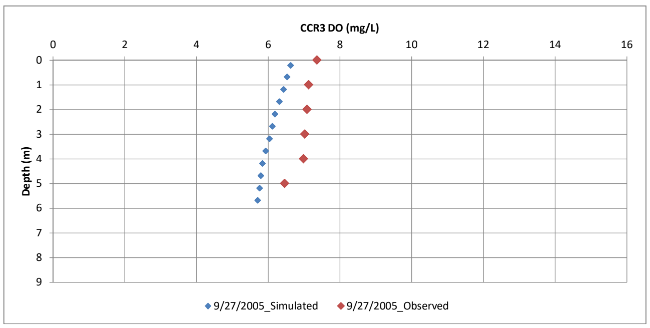

CCR2 DO (mg/L)
Depth (m)
8/3/2005_Simulated
8/3/2005_Observed

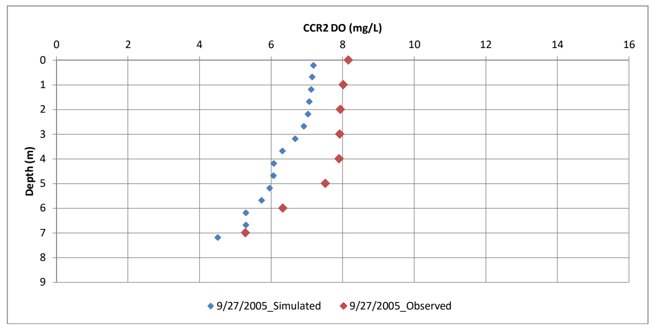

CCR3 DO (mg/L)
Depth (m)
8/23/2005_Simulated
8/23/2005_Observed

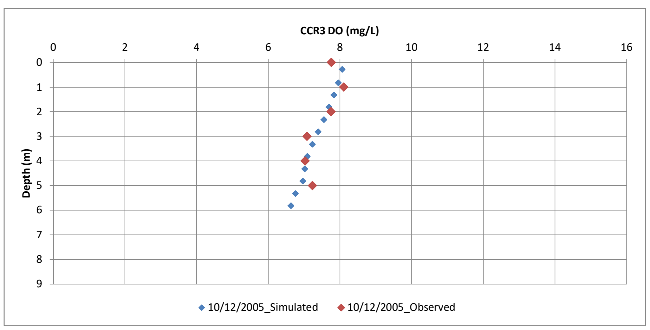

CCR2 DO (mg/L)
Depth (m)
8/23/2005_Simulated
8/23/2005_Observed

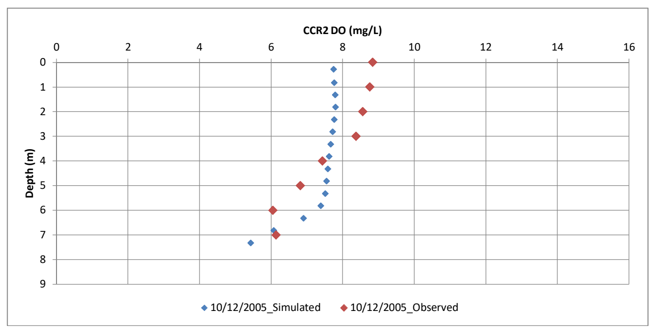

CCR3 DO (mg/L)
Depth (m)
9/14/2005_Simulated
9/14/2005_Observed

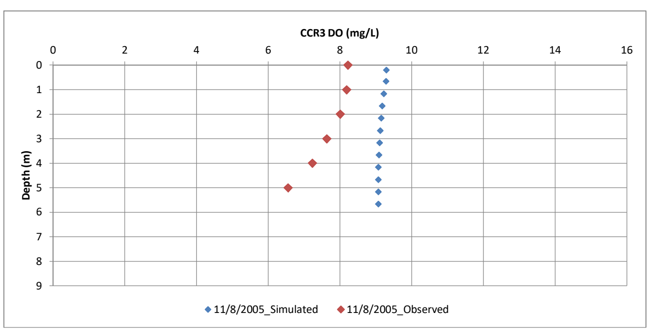

CCR2 DO (mg/L)
Depth (m)
9/14/2005_Simulated
9/14/2005_Observed

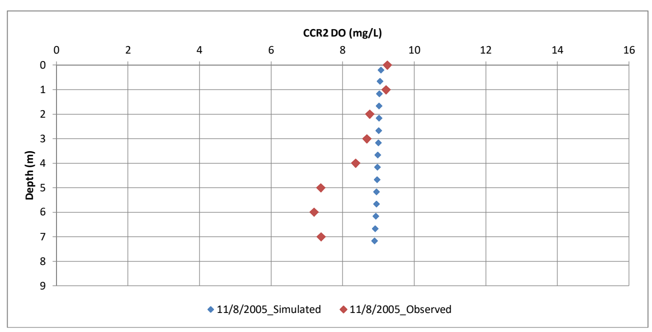

CCR3 DO (mg/L)
Depth (m)
9/27/2005_Simulated
9/27/2005_Observed

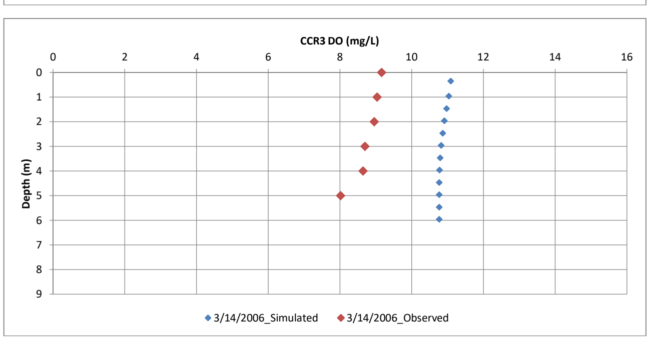

CCR2 DO (mg/L)
Depth (m)
9/27/2005_Simulated
9/27/2005_Observed

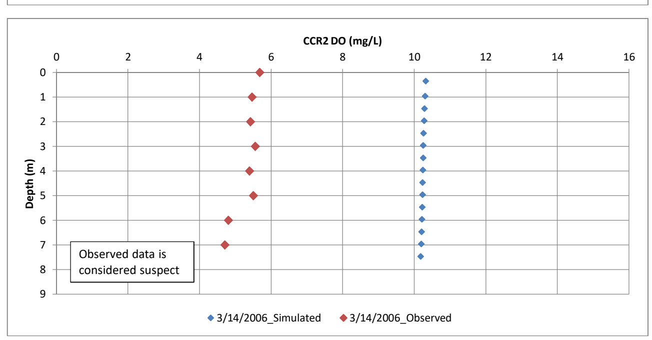

CCR3 DO (mg/L)
Depth (m)
10/12/2005_Simulated
10/12/2005_Observed

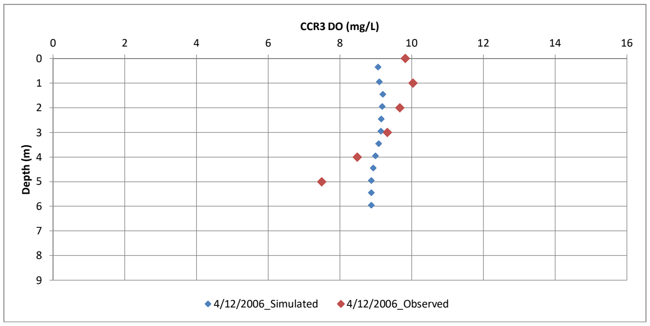

CCR2 DO (mg/L)
Depth (m)
10/12/2005_Simulated
10/12/2005_Observed

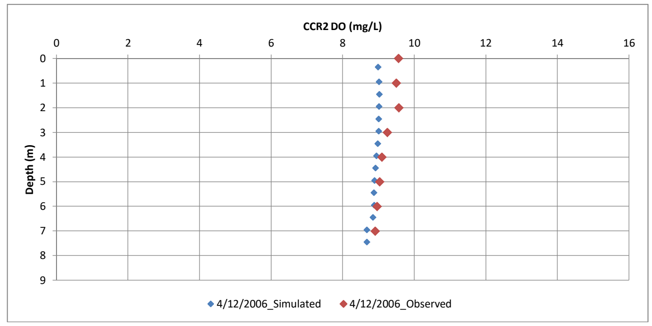

CCR3 DO (mg/L)
Depth (m)
11/8/2005_Simulated
11/8/2005_Observed

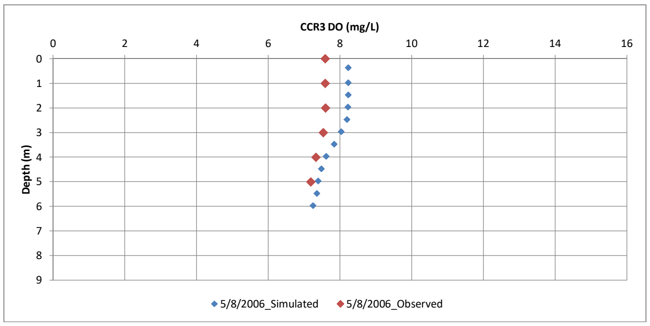

CCR2 DO (mg/L)
Depth (m)
11/8/2005_Simulated
11/8/2005_Observed

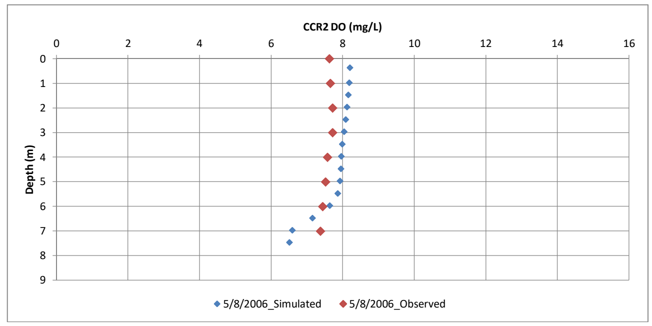

CCR3 DO (mg/L)
Depth (m)
3/14/2006_Simulated
3/14/2006_Observed

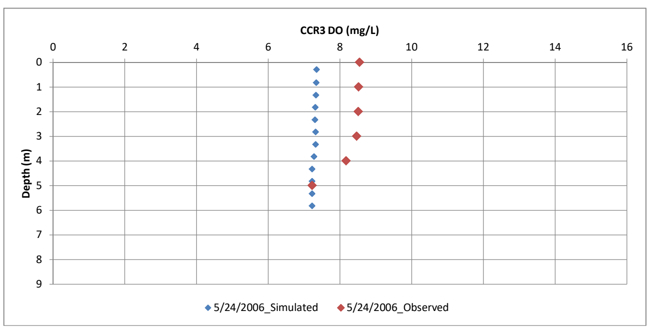

CCR2 DO (mg/L)
Depth (m)
Observed data is considered suspect
3/14/2006_Simulated
3/14/2006_Observed

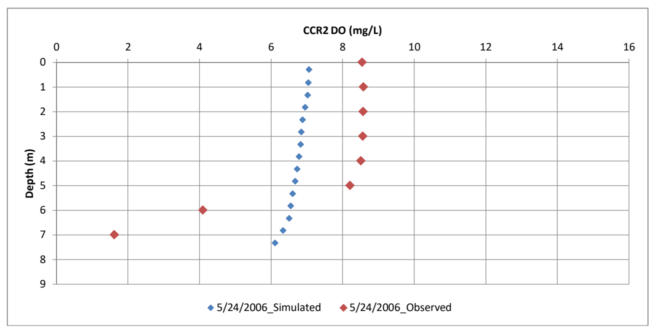

CCR3 DO (mg/L)
Depth (m)
4/12/2006_Simulated
4/12/2006_Observed

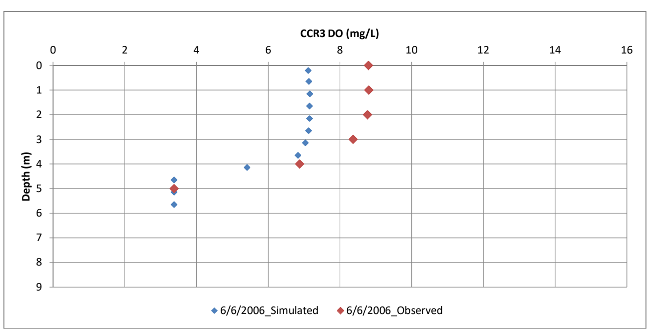

CCR2 DO (mg/L)
Depth (m)
4/12/2006_Simulated
4/12/2006_Observed

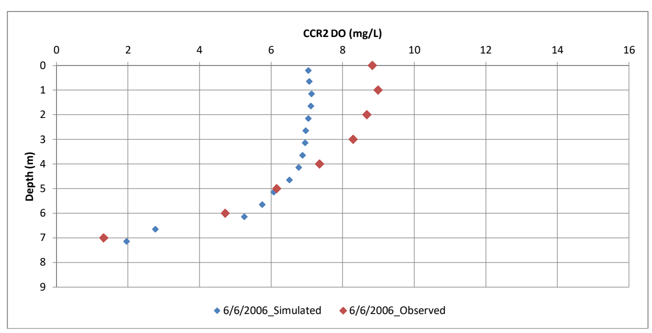

CCR3 DO (mg/L)
Depth (m)
5/8/2006_Simulated
5/8/2006_Observed

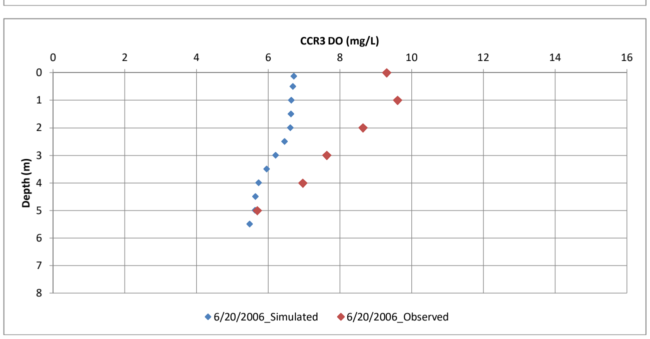

CCR2 DO (mg/L)
Depth (m)
5/8/2006_Simulated
5/8/2006_Observed

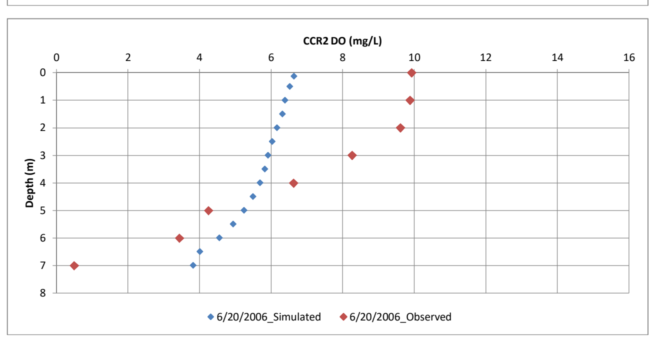

CCR3 DO (mg/L)
Depth (m)
5/24/2006_Simulated
5/24/2006_Observed

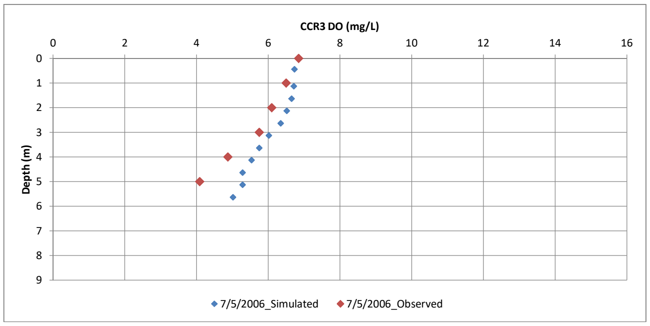

CCR2 DO (mg/L)
Depth (m)
5/24/2006_Simulated
5/24/2006_Observed

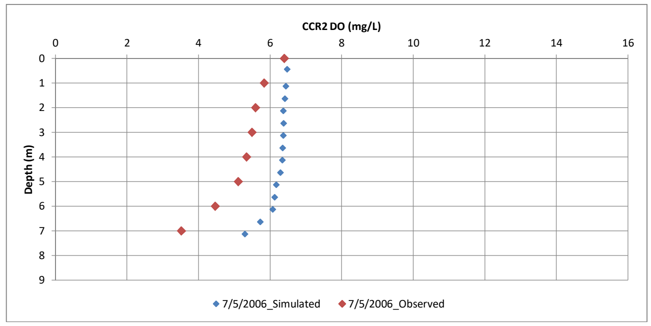

CCR3 DO (mg/L)
Depth (m)
6/6/2006_Simulated
6/6/2006_Observed

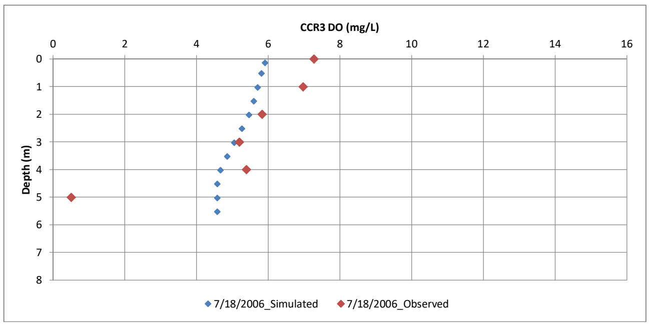

CCR2 DO (mg/L)
Depth (m)
6/6/2006_Simulated
6/6/2006_Observed

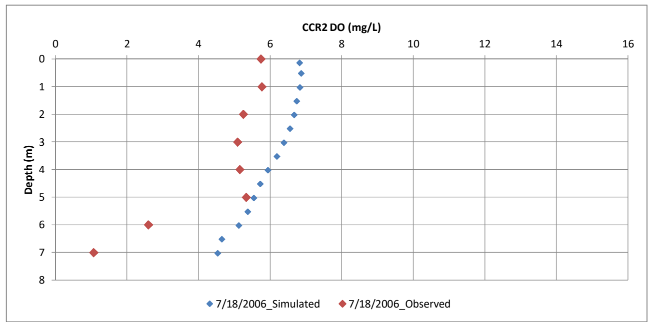

CCR3 DO (mg/L)
Depth (m)
6/20/2006_Simulated
6/20/2006_Observed

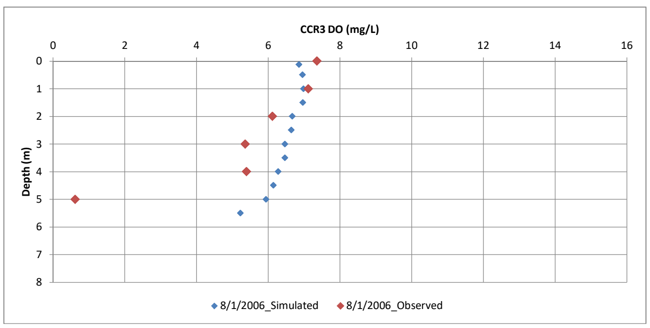

CCR2 DO (mg/L)
Depth (m)
6/20/2006_Simulated
6/20/2006_Observed

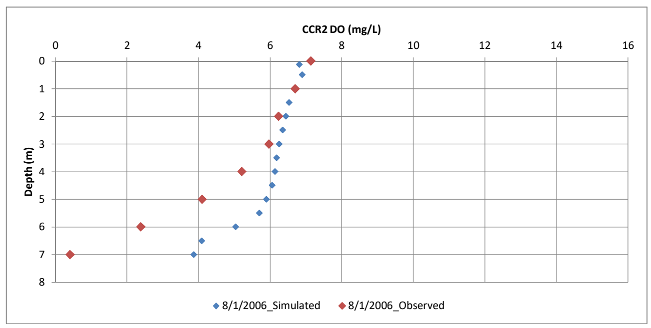

CCR3 DO (mg/L)
Depth (m)
7/5/2006_Simulated
7/5/2006_Observed

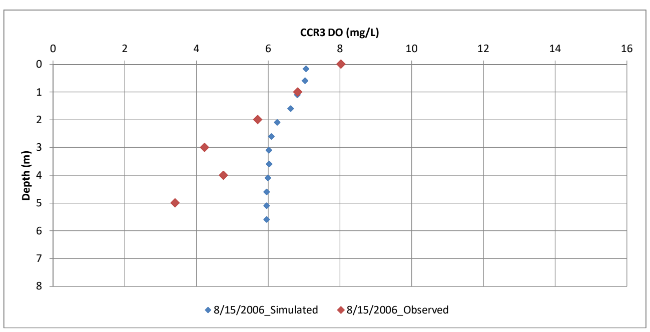

CCR2 DO (mg/L)
Depth (m)
7/5/2006_Simulated
7/5/2006_Observed

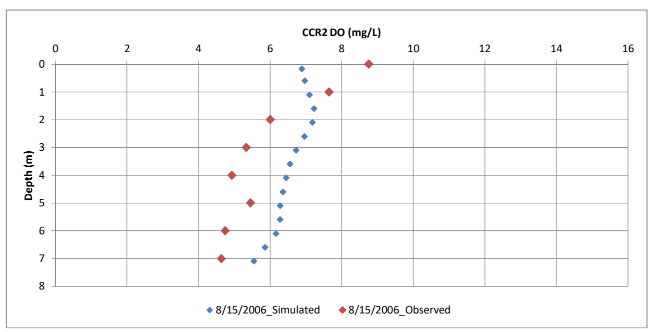

CCR3 DO (mg/L)
Depth (m)
7/18/2006_Simulated
7/18/2006_Observed

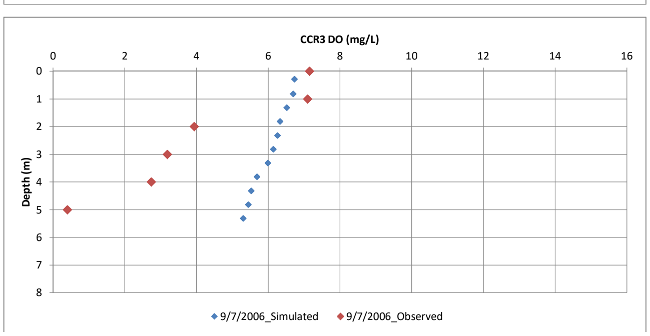

CCR2 DO (mg/L)
Depth (m)
7/18/2006_Simulated
7/18/2006_Observed

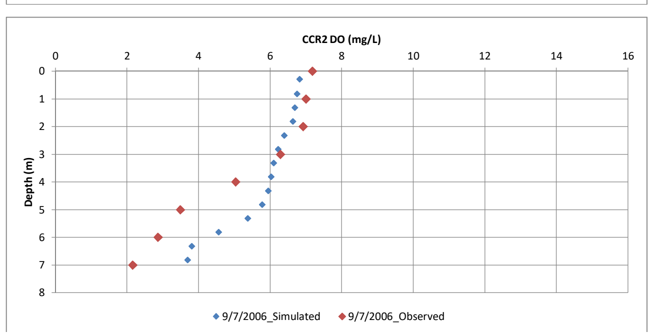

CCR3 DO (mg/L)
Depth (m)
8/1/2006_Simulated
8/1/2006_Observed

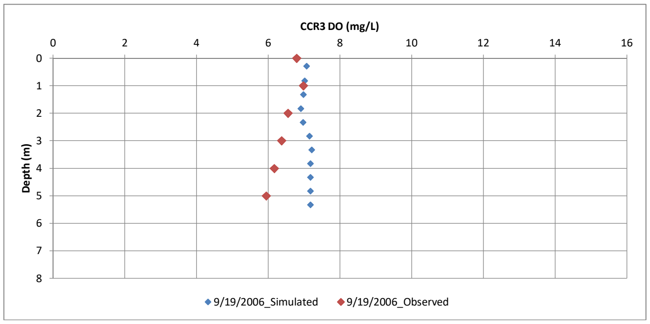

CCR2 DO (mg/L)
Depth (m)
8/1/2006_Simulated
8/1/2006_Observed

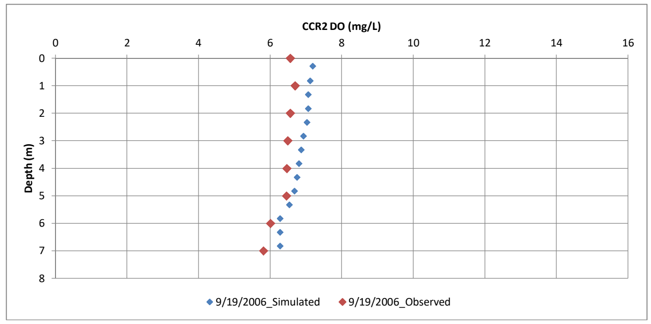

CCR3 DO (mg/L)
Depth (m)
8/15/2006_Simulated
8/15/2006_Observed

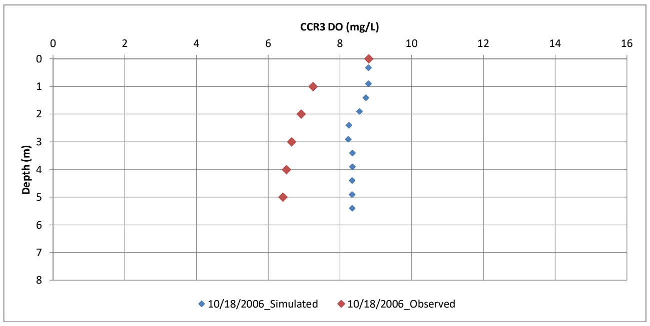

CCR2 DO (mg/L)
Depth (m)
8/15/2006_Simulated
8/15/2006_Observed

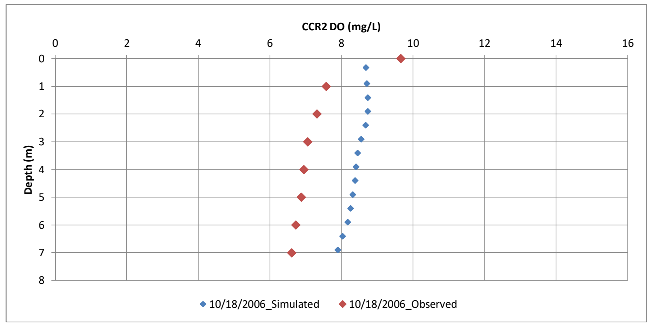

CCR3 DO (mg/L)
Depth (m)
9/7/2006_Simulated
9/7/2006_Observed

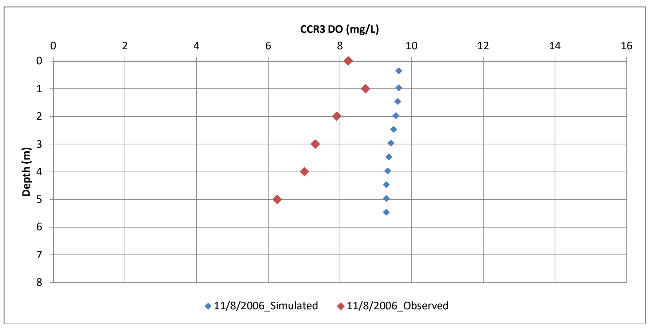

CCR2 DO (mg/L)
Depth (m)
9/7/2006_Simulated
9/7/2006_Observed

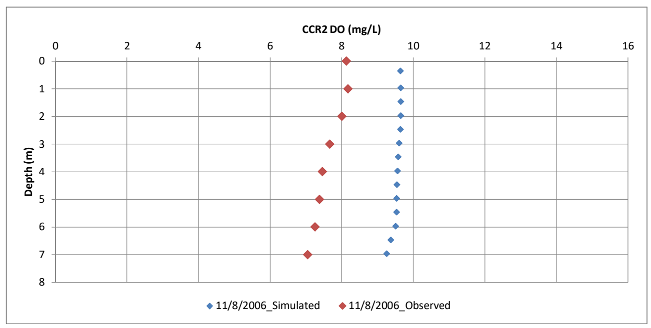

CCR3 DO (mg/L)
Depth (m)
9/19/2006_Simulated
9/19/2006_Observed

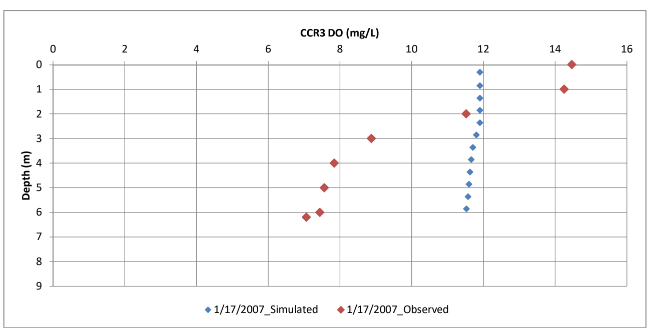

CCR2 DO (mg/L)
Depth (m)
9/19/2006_Simulated
9/19/2006_Observed

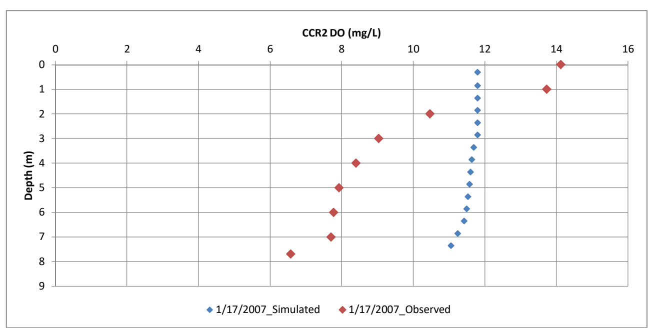

CCR3 DO (mg/L)
Depth (m)
10/18/2006_Simulated
10/18/2006_Observed

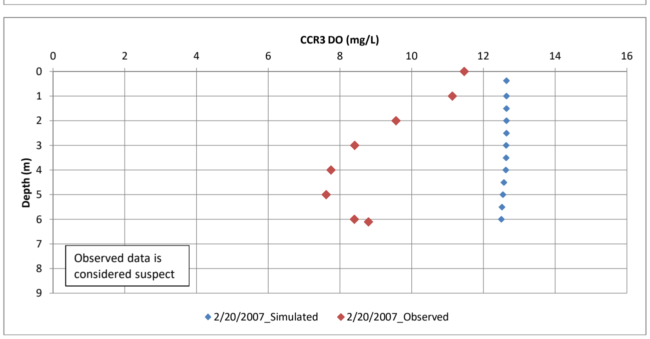

CCR2 DO (mg/L)
Depth (m)
10/18/2006_Simulated
10/18/2006_Observed

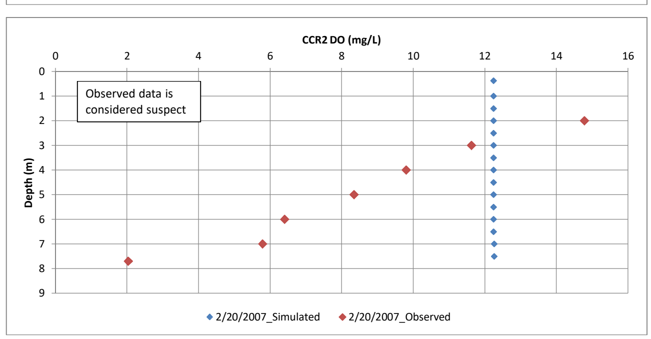

CCR3 DO (mg/L)
Depth (m)
11/8/2006_Simulated
11/8/2006_Observed

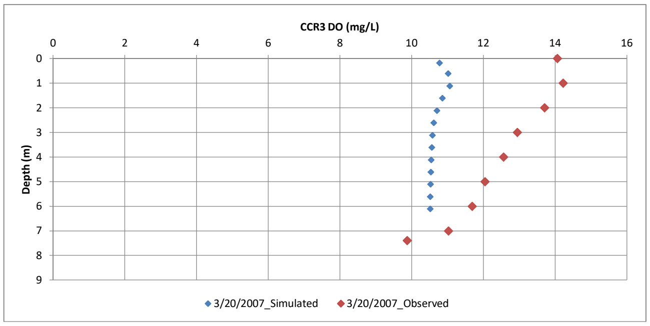

CCR2 DO (mg/L)
Depth (m)
11/8/2006_Simulated
11/8/2006_Observed

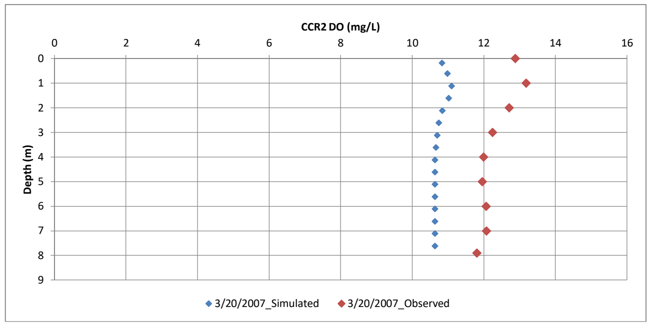

CCR3 DO (mg/L)
Depth (m)
1/17/2007_Simulated
1/17/2007_Observed

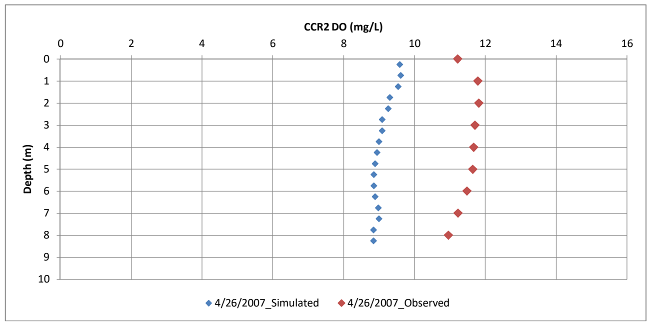

CCR2 DO (mg/L)
Depth (m)
1/17/2007_Simulated
1/17/2007_Observed

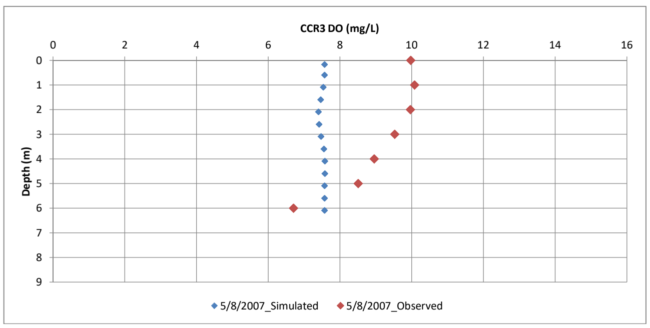

CCR3 DO (mg/L)
Depth (m)
Observed data is considered suspect
2/20/2007_Simulated
2/20/2007_Observed

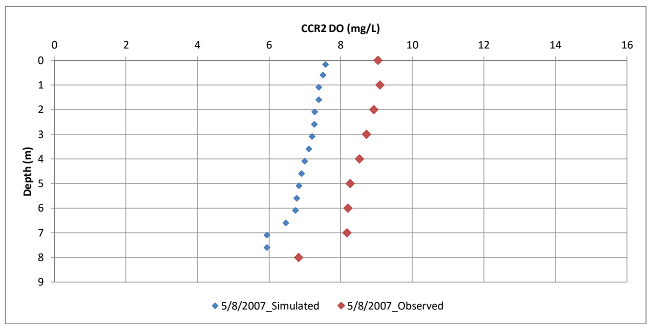

CCR2 DO (mg/L)
Depth (m)
Observed data is considered suspect
2/20/2007_Simulated
2/20/2007_Observed

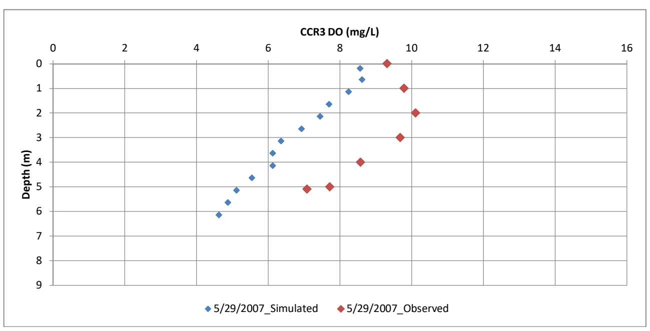

CCR3 DO (mg/L)
Depth (m)
3/20/2007_Simulated
3/20/2007_Observed

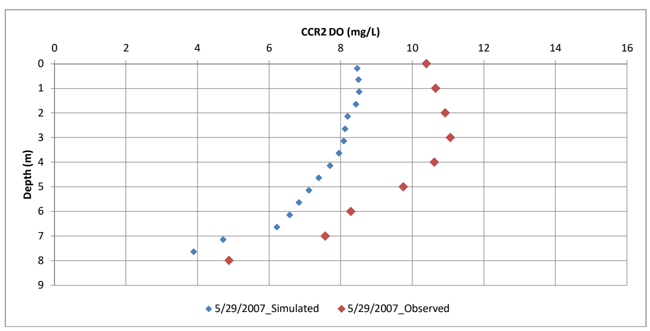

CCR2 DO (mg/L)
Depth (m)
3/20/2007_Simulated
3/20/2007_Observed

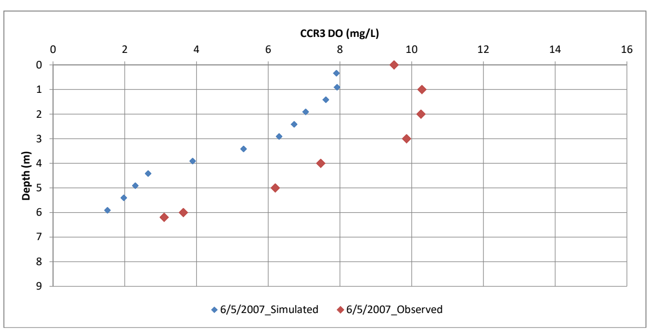

CCR2 DO (mg/L)
Depth (m)
4/26/2007_Simulated
4/26/2007_Observed

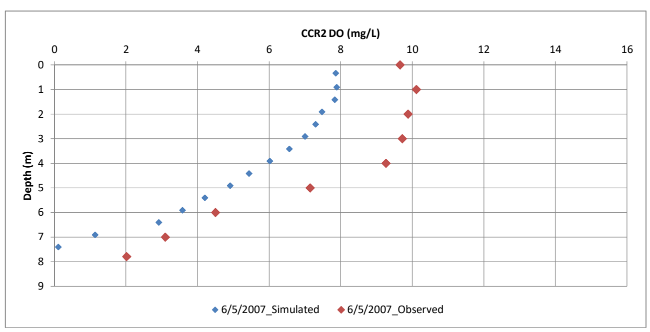

CCR3 DO (mg/L)
Depth (m)
5/8/2007_Simulated
5/8/2007_Observed

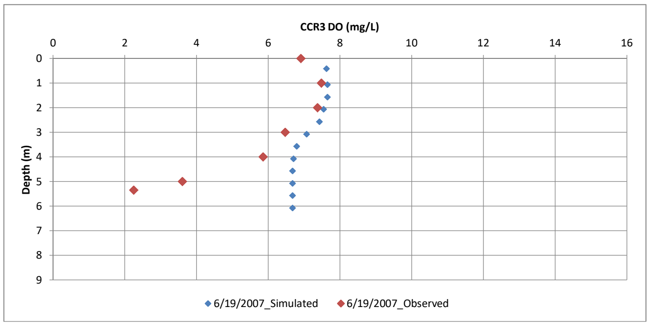

CCR2 DO (mg/L)
Depth (m)
5/8/2007_Simulated
5/8/2007_Observed

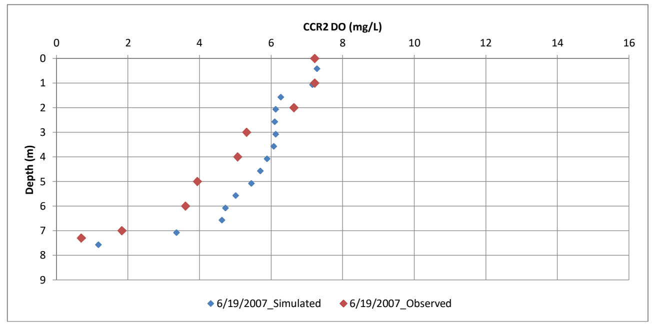

CCR3 DO (mg/L)
Depth (m)
5/29/2007_Simulated
5/29/2007_Observed

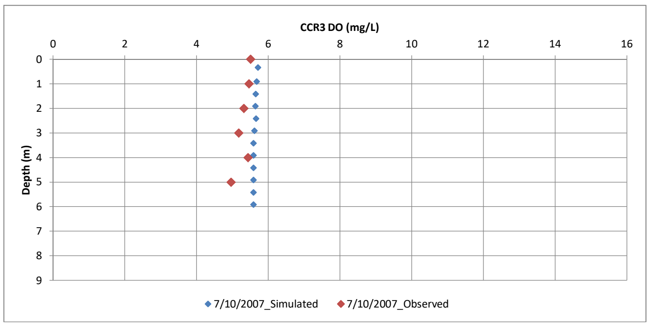

CCR2 DO (mg/L)
Depth (m)
5/29/2007_Simulated
5/29/2007_Observed

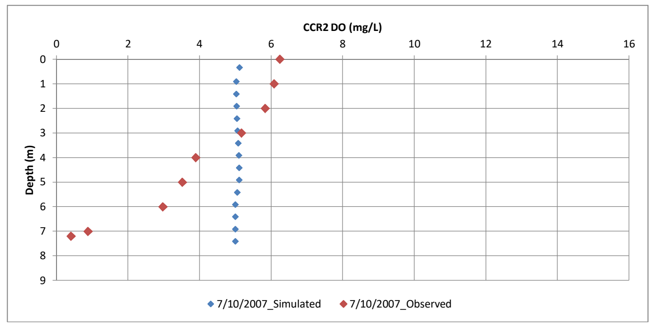

CCR3 DO (mg/L)
Depth (m)
6/5/2007_Simulated
6/5/2007_Observed

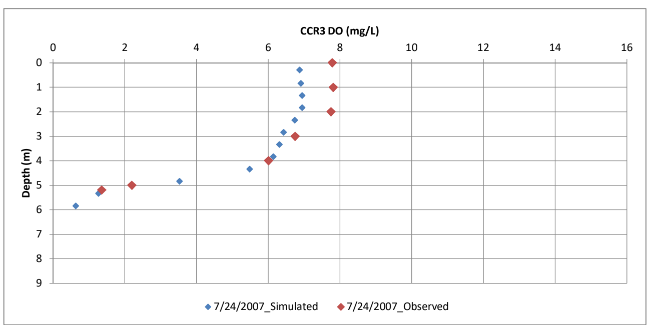

CCR2 DO (mg/L)
Depth (m)
6/5/2007_Simulated
6/5/2007_Observed

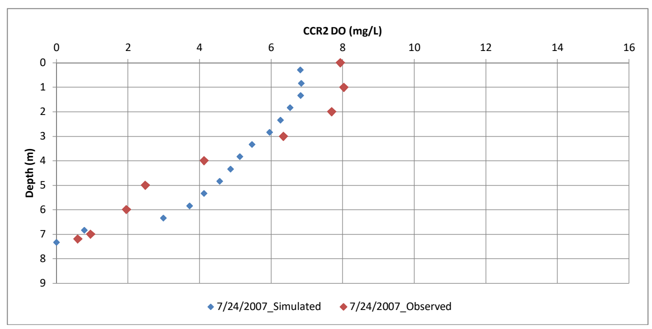

CCR3 DO (mg/L)
Depth (m)
6/19/2007_Simulated
6/19/2007_Observed

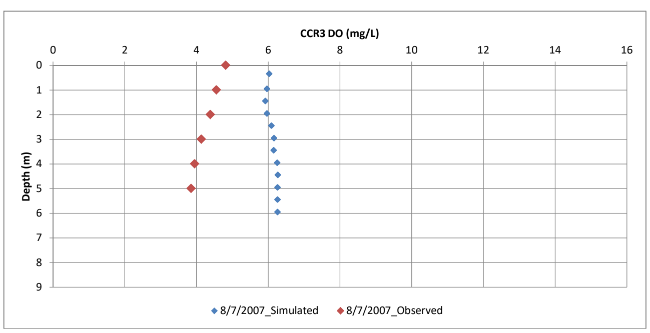

CCR2 DO (mg/L)
Depth (m)
6/19/2007_Simulated
6/19/2007_Observed

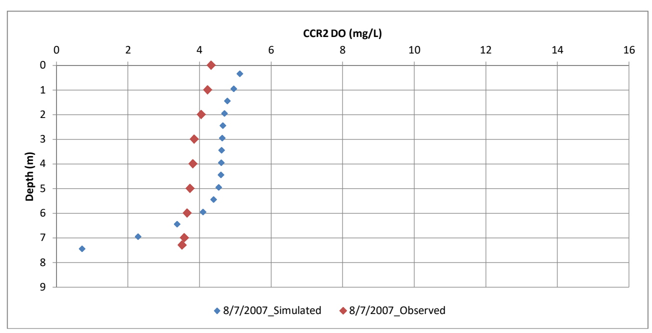

CCR3 DO (mg/L)
Depth (m)
7/10/2007_Simulated
7/10/2007_Observed

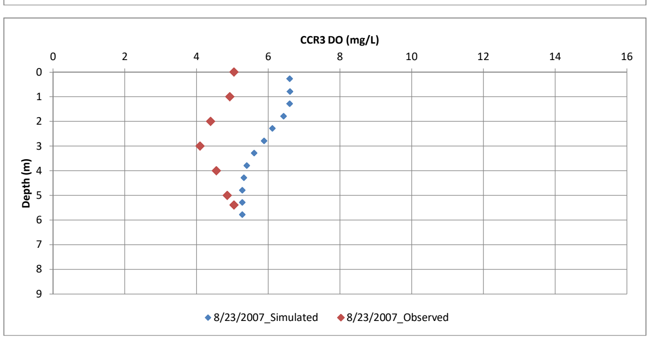

CCR2 DO (mg/L)
Depth (m)
7/10/2007_Simulated
7/10/2007_Observed

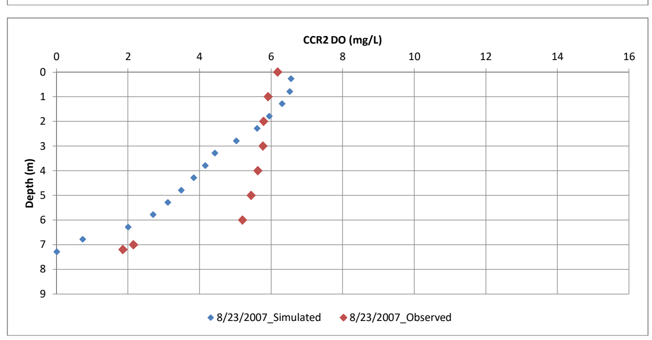

CCR3 DO (mg/L)
Depth (m)
7/24/2007_Simulated
7/24/2007_Observed


CCR2 DO (mg/L)
Depth (m)
7/24/2007_Simulated
7/24/2007_Observed


CCR3 DO (mg/L)
Depth (m)
8/7/2007_Simulated
8/7/2007_Observed


CCR2 DO (mg/L)
Depth (m)
8/7/2007_Simulated
8/7/2007_Observed


CCR3 DO (mg/L)
Depth (m)
8/23/2007_Simulated
8/23/2007_Observed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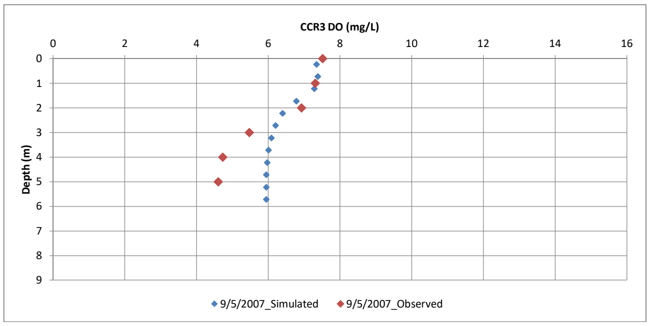
Depth (m)
8/23/2007_Simulated
8/23/2007_Observed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Depth (m)
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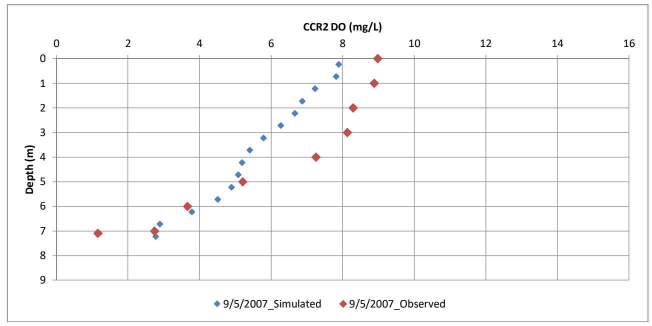
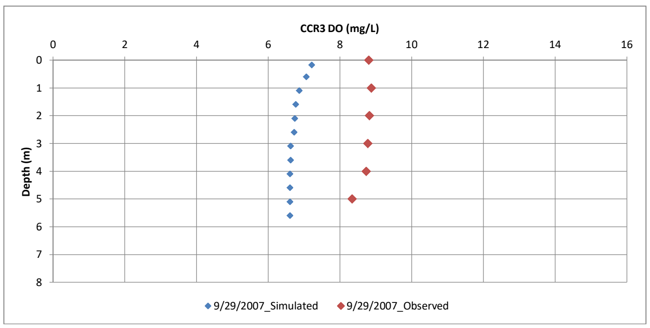
9/5/2007_Observed


CCR2 DO (mg/L)
Depth (m)
9/5/2007_Simulated
9/5/2007_Observed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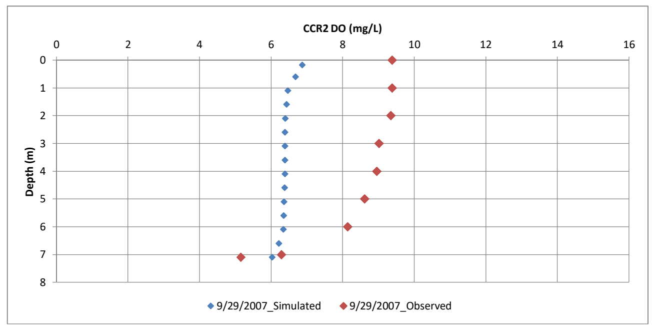
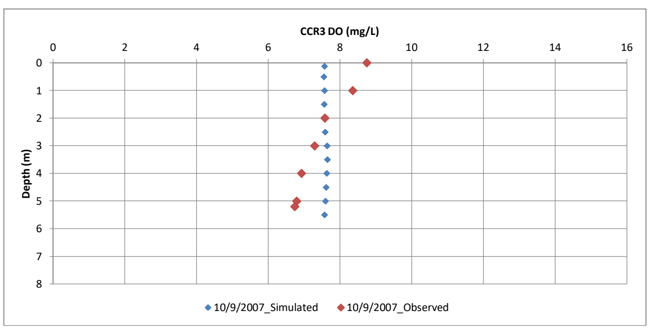
Depth (m)
9/29/2007_Simulated
9/29/2007_Observed


CCR2 DO (mg/L)
Depth (m)
9/29/2007_Simulated
9/29/2007_Observed

x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Depth (m)
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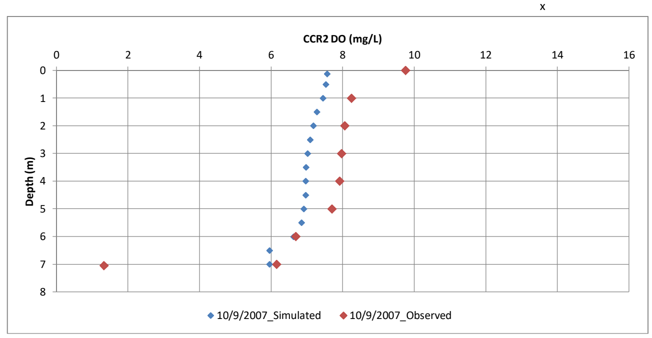
10/9/2007_Observed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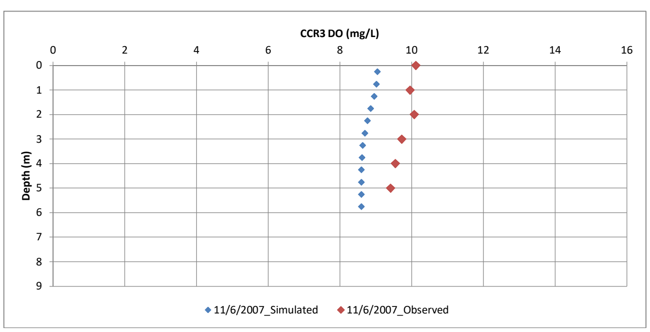
Depth (m)
10/9/2007_Simulated
10/9/2007_Observed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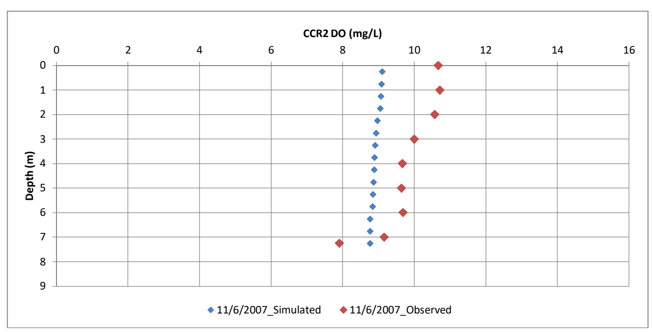
Depth (m)
11/6/2007_Simulated
11/6/2007_Observed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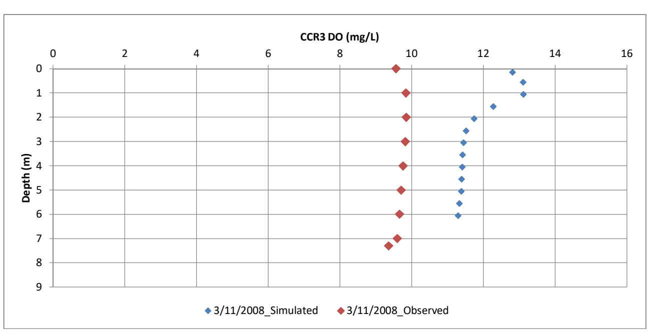
Depth (m)
11/6/2007_Simulated
11/6/2007_Observed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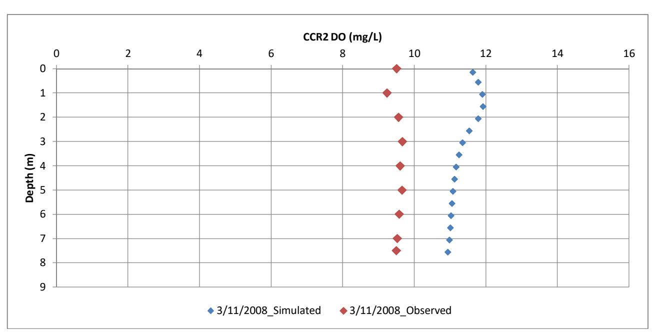
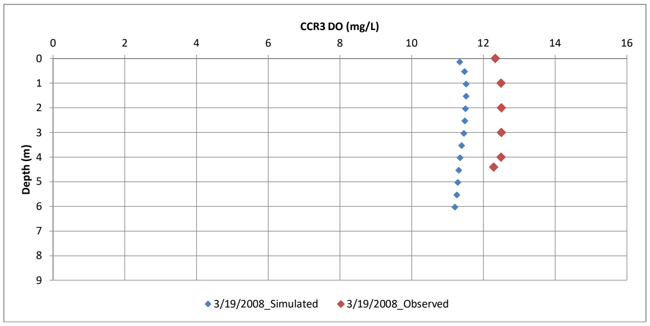
Depth (m)
3/11/2008_Simulated
3/11/2008_Observed


CCR2 DO (mg/L)
Depth (m)
3/11/2008_Simulated
3/11/2008_Observed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Depth (m)
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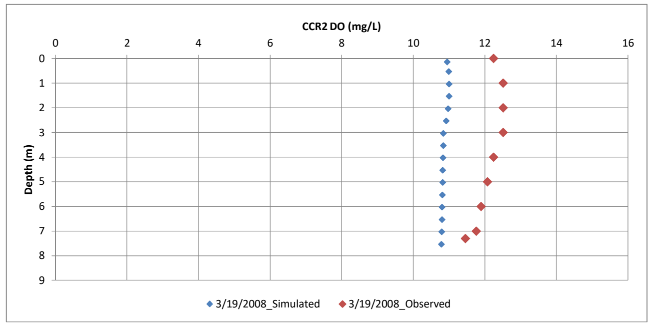
3/19/2008_Simulated
3/19/2008_Observed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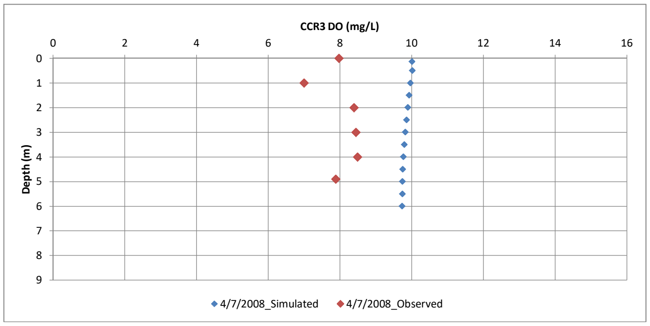
Depth (m)
0 1 2 3 4 5 6 7 8 9
3/19/2008_Simulated
3/19/2008_Observed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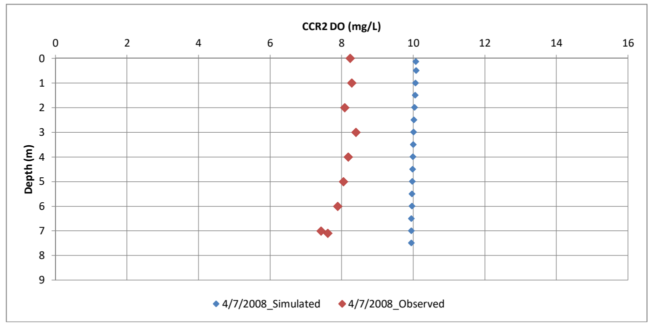
Depth (m)
0 1 2 3 4 5 6 7 8 9
4/7/2008_Simulated
4/7/2008_Observed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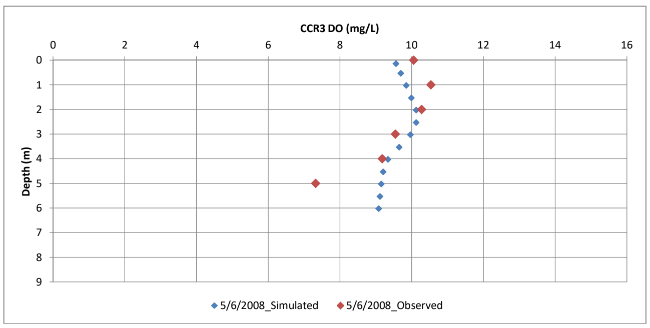
Depth (m)
0 1 2 3 4 5 6 7 8 9
4/7/2008_Simulated
4/7/2008_Observed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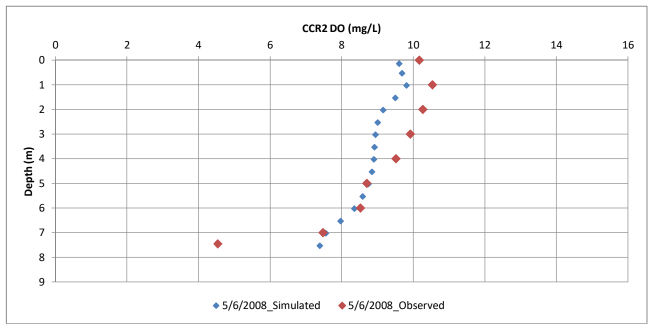
Depth (m)
0 1 2 3 4 5 6 7 8 9
5/6/2008_Simulated
5/6/2008_Observed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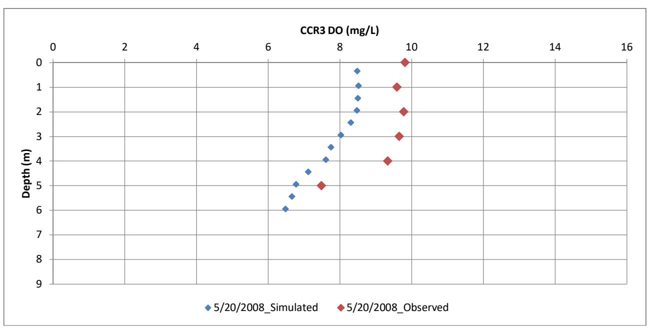
Depth (m)
0 1 2 3 4 5 6 7 8 9
5/6/2008_Simulated
5/6/2008_Observed


CCR3 DO (mg/L)
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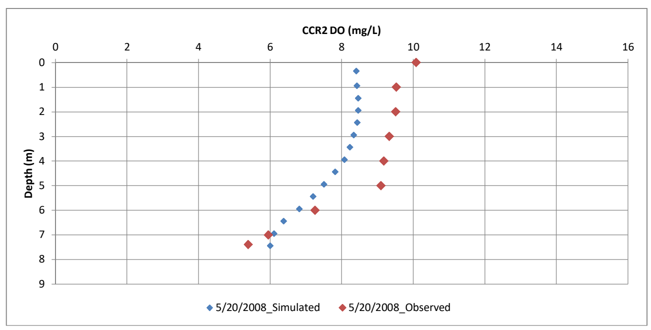
Depth (m)
0 1 2 3 4 5 6 7 8 9
5/20/2008_Simulated
5/20/2008_Observed


CCR2 DO (mg/L)
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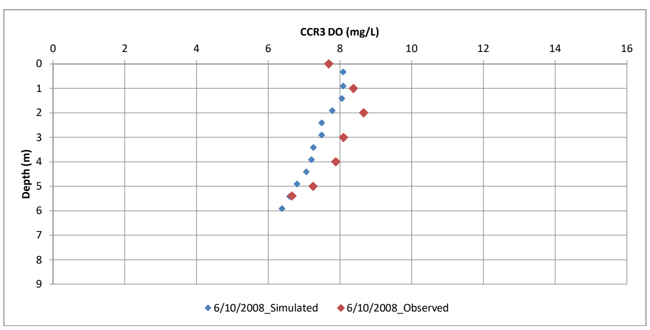
Depth (m)
0 1 2 3 4 5 6 7 8 9
5/20/2008_Simulated
5/20/2008_Observed


CCR3 DO (mg/L)
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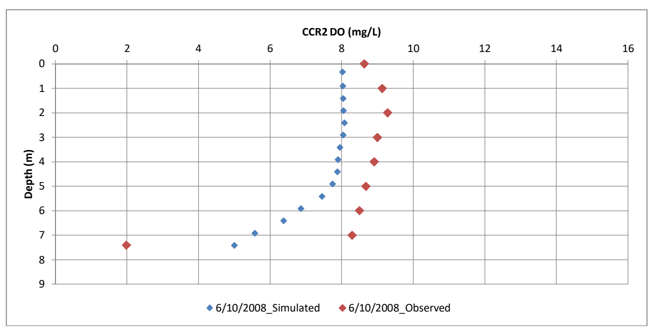
Depth (m)
0 1 2 3 4 5 6 7 8 9
6/10/2008_Simulated
6/10/2008_Observed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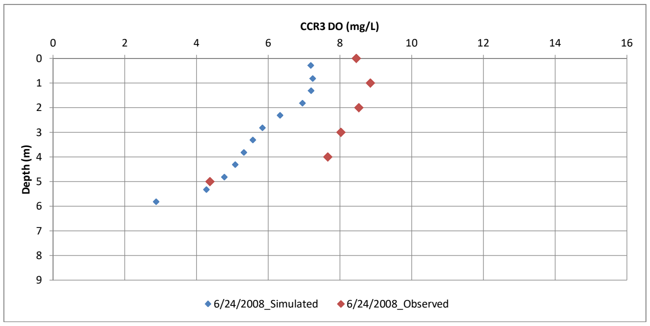
Depth (m)
0 1 2 3 4 5 6 7 8 9
6/10/2008_Simulated
6/10/2008_Observed


CCR3 DO (mg/L)
Depth (m)
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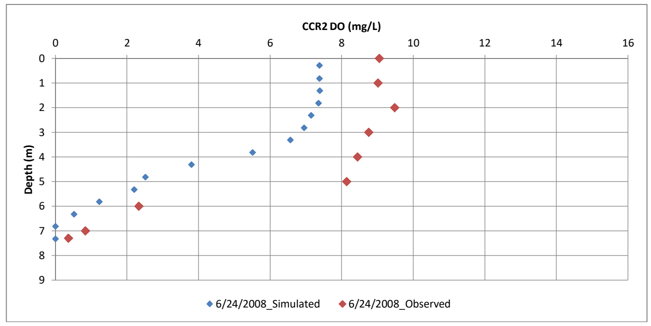
6/24/2008_Observed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Depth (m)
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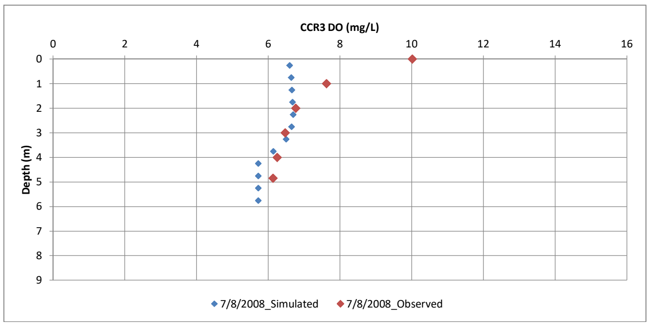
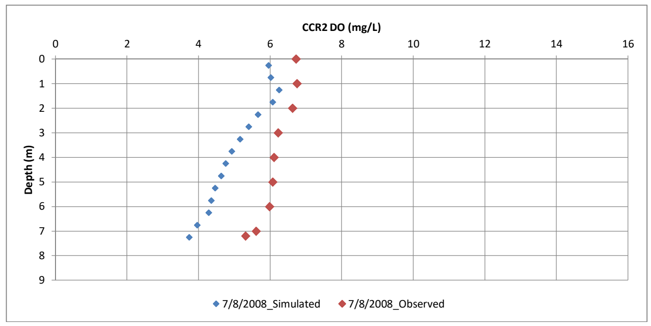
6/24/2008_Observed


CCR3 DO (mg/L)
Depth (m)
7/8/2008_Simulated
7/8/2008_Observed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Depth (m)
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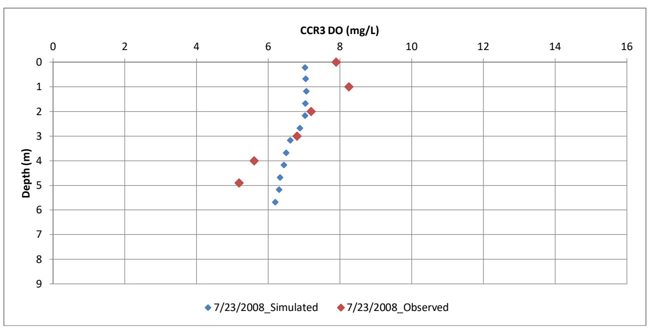
7/8/2008_Observed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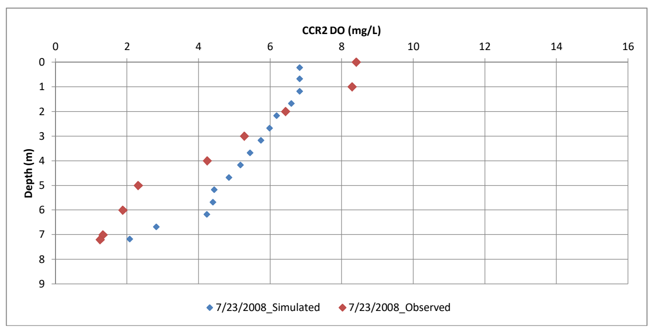
Depth (m)
7/23/2008_Simulated
7/23/2008_Observed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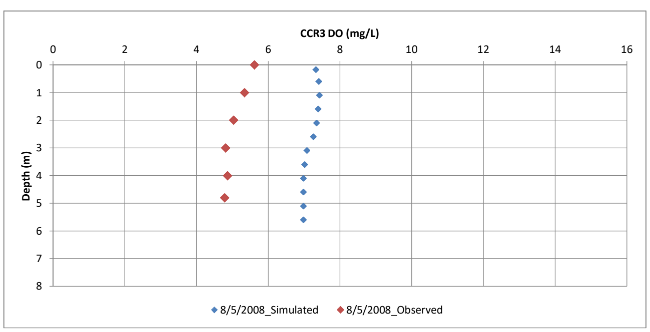
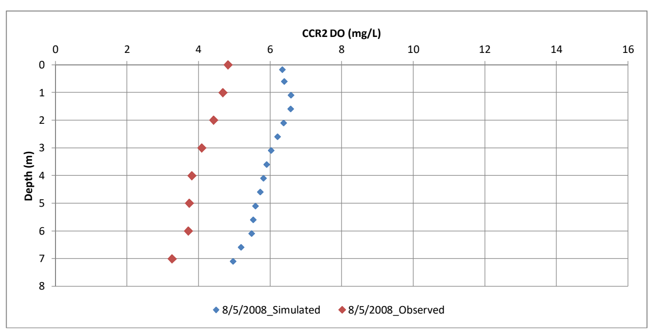
Depth (m)
7/23/2008_Simulated
7/23/2008_Observed


CCR3 DO (mg/L)
Depth (m)
8/5/2008_Simulated
8/5/2008_Observed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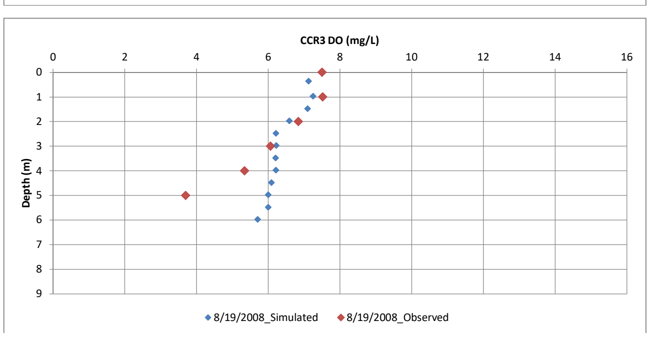
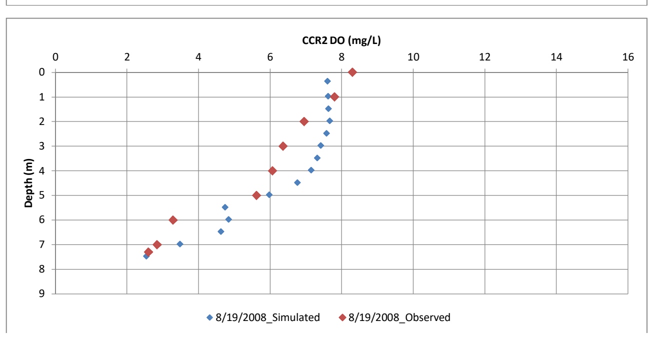
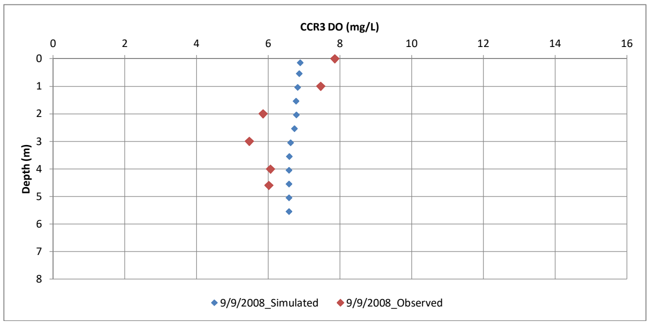
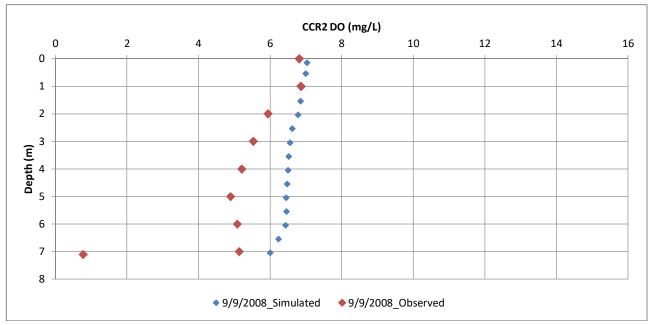
Depth (m)
8/5/2008_Simulated
8/5/2008_Observed


CCR3 DO (mg/L)
Depth (m)
8/19/2008_Simulated
8/19/2008_Observed


CCR2 DO (mg/L)
Depth (m)
8/19/2008_Simulated
8/19/2008_Observed


CCR3 DO (mg/L)
Depth (m)
9/9/2008_Simulated
9/9/2008_Observed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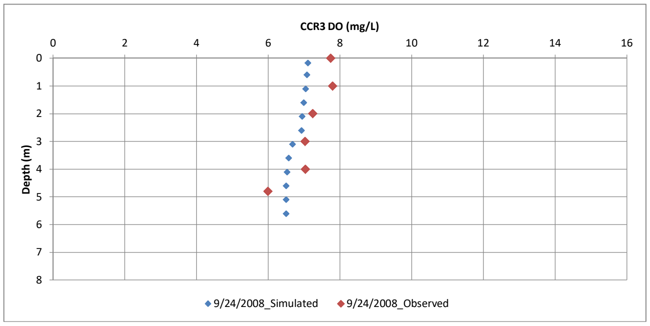
Depth (m)
9/9/2008_Simulated
9/9/2008_Observed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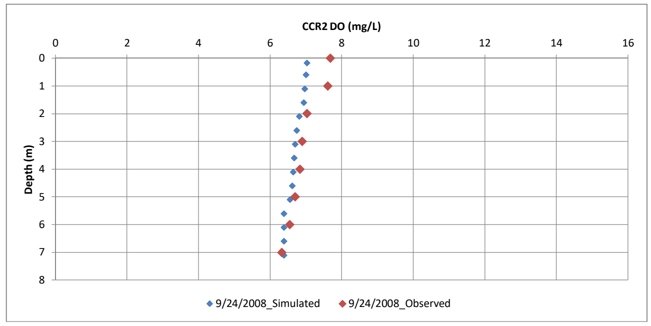
Depth (m)
9/24/2008_Simulated
9/24/2008_Observed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Depth (m)
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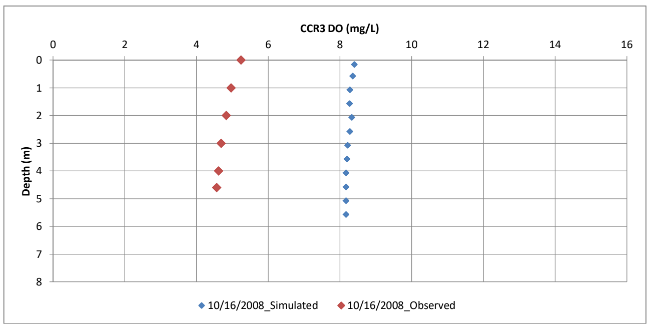
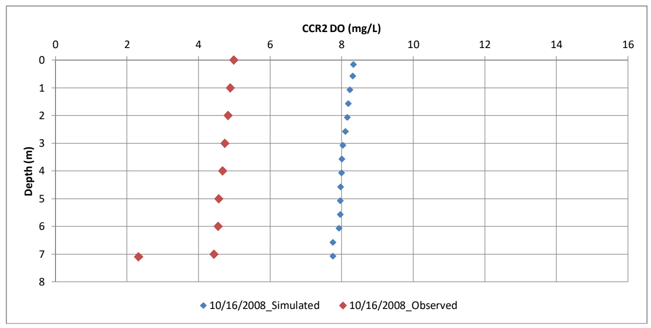
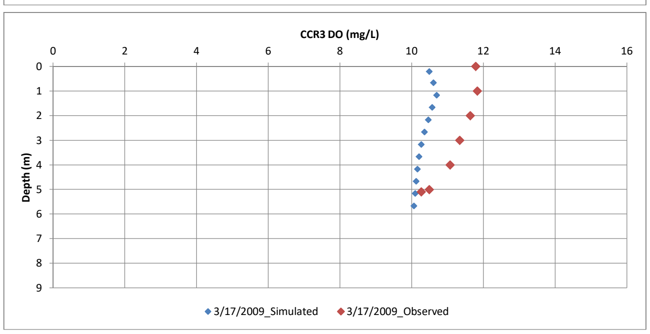
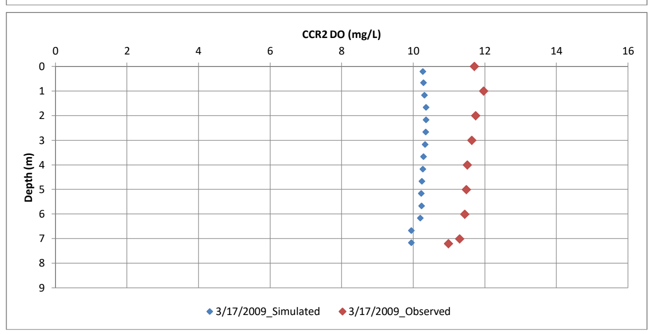

CCR3 DO (mg/L)
Depth (m)
10/16/2008_Simulated
10/16/2008_Observed


CCR2 DO (mg/L)
Depth (m)
10/16/2008_Simulated
10/16/2008_Observed


CCR3 DO (mg/L)
Depth (m)
3/17/2009_Simulated
3/17/2009_Observed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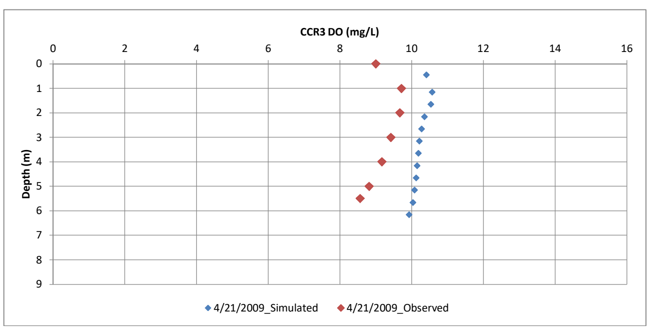
Depth (m)
3/17/2009_Simulated
3/17/2009_Observed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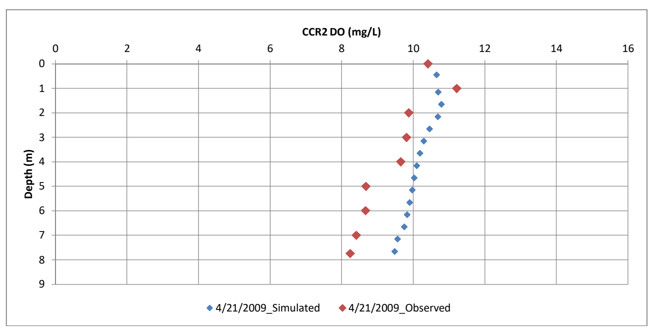
Depth (m)
4/21/2009_Simulated
4/21/2009_Observed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Depth (m)
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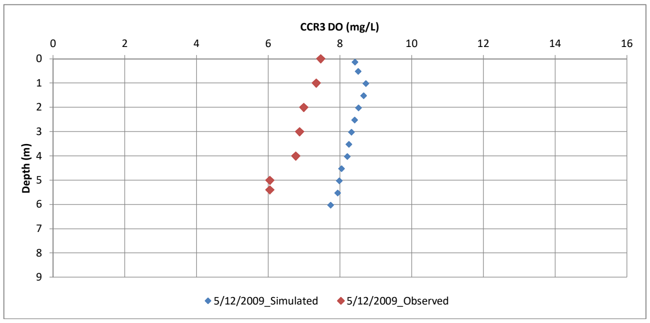
4/21/2009_Observed


CCR3 DO (mg/L)
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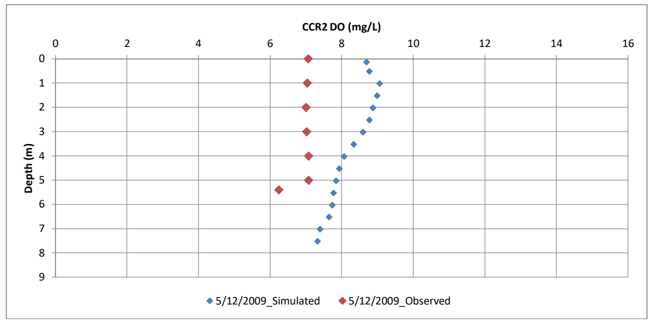
Depth (m)
0 1 2 3 4 5 6 7 8 9
5/12/2009_Simulated
5/12/2009_Observed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Depth (m)
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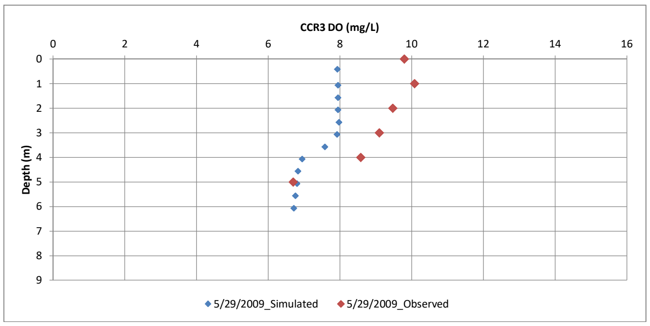
5/12/2009_Simulated
5/12/2009_Observed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Depth (m)
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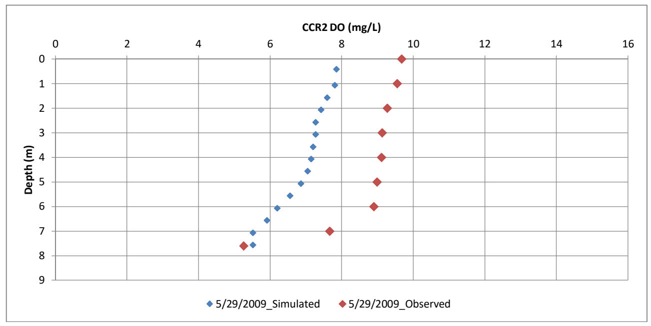
5/29/2009_Simulated
5/29/2009_Observed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Depth (m)
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5/29/2009_Simulated
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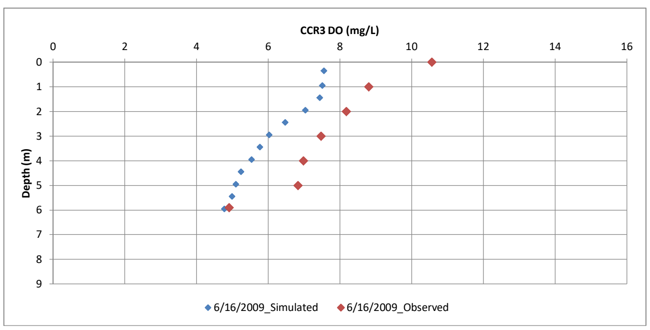
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Depth (m)
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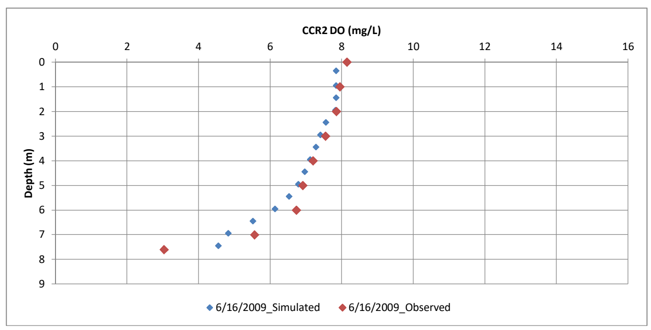
6/16/2009_Simulated
6/16/2009_Observed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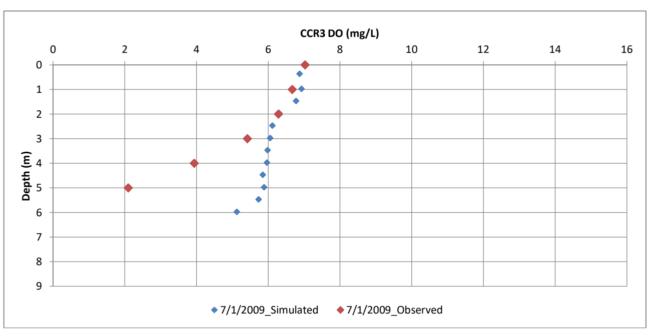
Depth (m)
0 1 2 3 4 5 6 7 8 9
6/16/2009_Simulated
6/16/2009_Observed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Depth (m)
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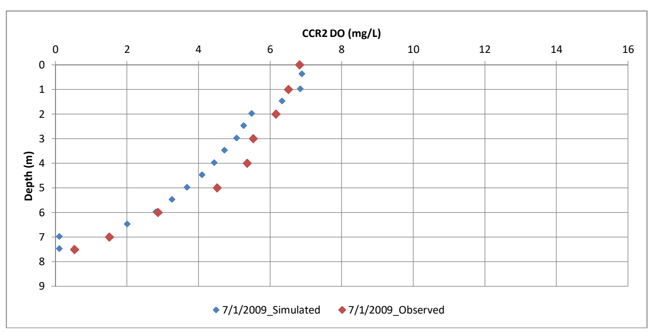
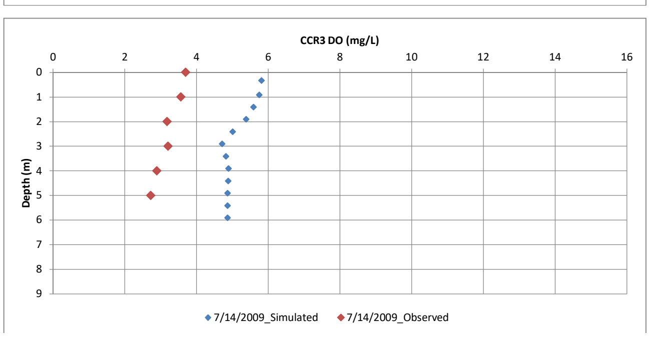
7/1/2009_Simulated
7/1/2009_Observed


CCR2 DO (mg/L)
0 2 4 6 8 10 12 14 16
Depth (m)
0 1 2 3 4 5 6 7 8 9
7/1/2009_Simulated
7/1/2009_Observed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Depth (m)
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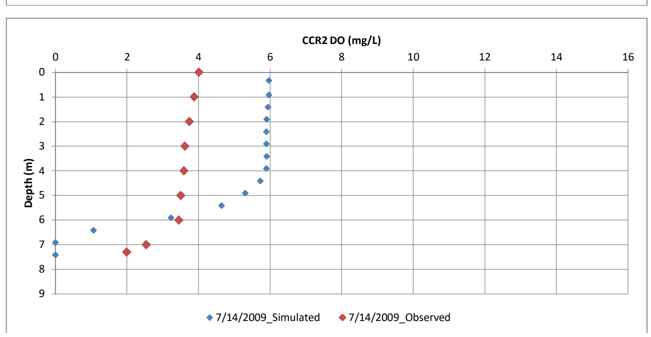
7/14/2009_Simulated
7/14/2009_Observed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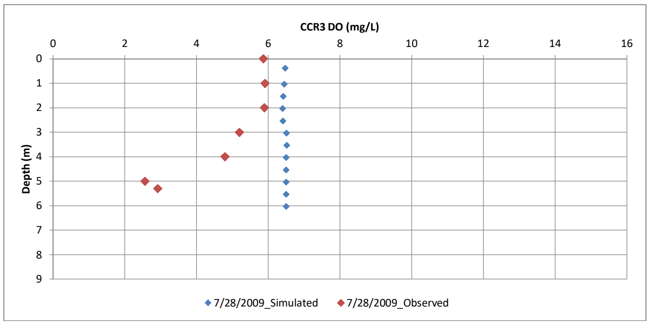
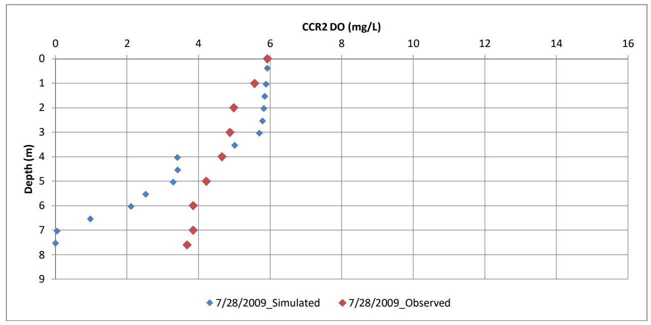
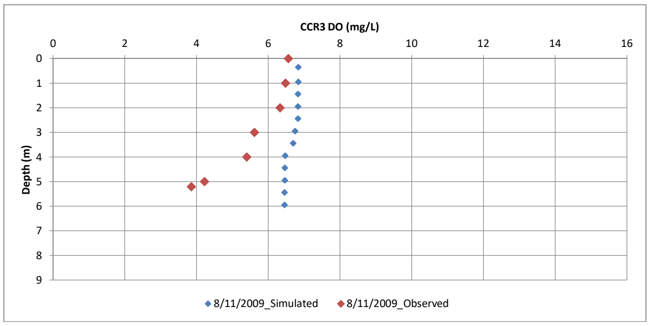
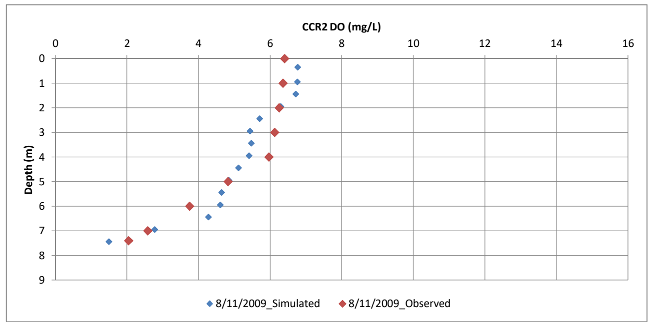
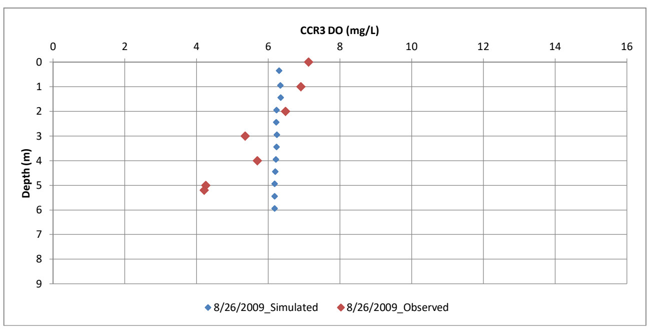
Depth (m)
0 1 2 3 4 5 6 7 8 9
7/14/2009_Simulated
7/14/2009_Observed

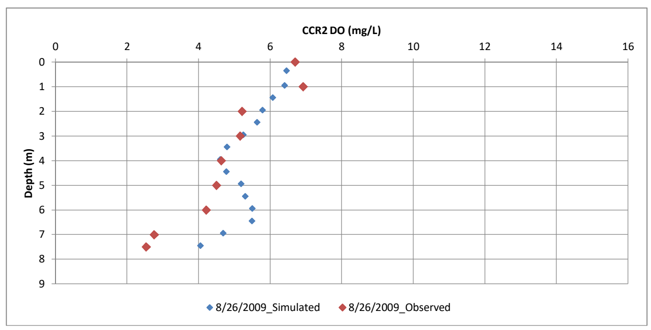

CCR3 DO (mg/L)
Depth (m)
7/28/2009_Simulated
7/28/2009_Observed

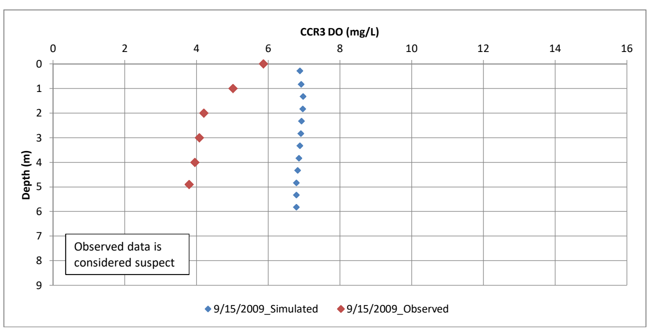

CCR2 DO (mg/L)
Depth (m)
7/28/2009_Simulated
7/28/2009_Observed

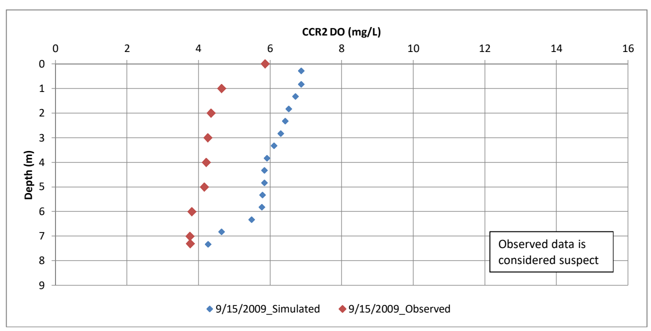

CCR3 DO (mg/L)
Depth (m)
8/11/2009_Simulated
8/11/2009_Observed

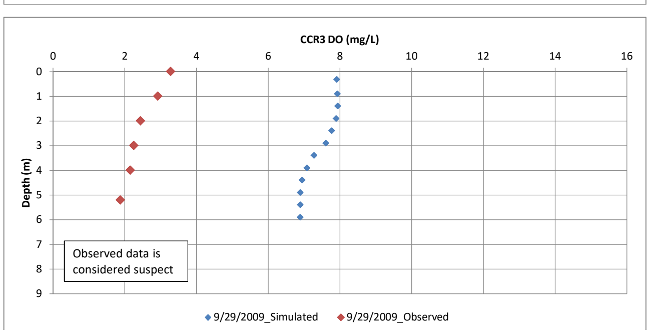

CCR2 DO (mg/L)
Depth (m)
8/11/2009_Simulated
8/11/2009_Observed

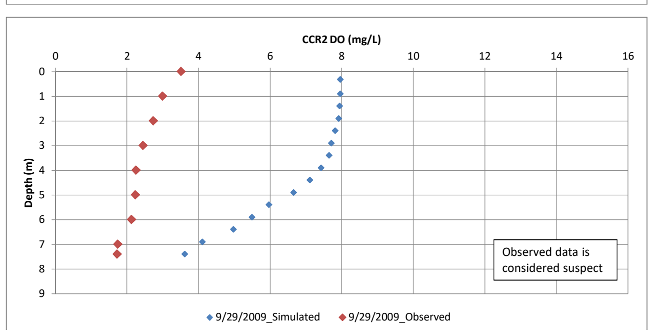

CCR3 DO (mg/L)
Depth (m)
8/26/2009_Simulated
8/26/2009_Observed

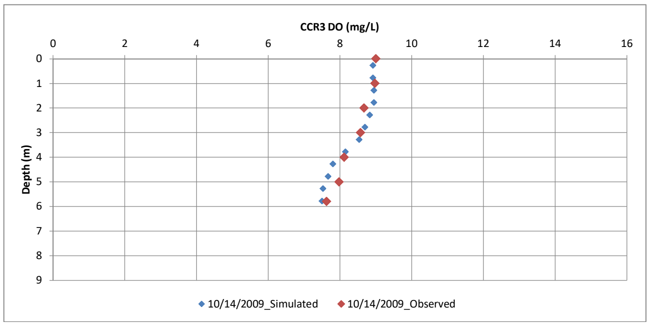

CCR2 DO (mg/L)
Depth (m)
8/26/2009_Simulated
8/26/2009_Observed

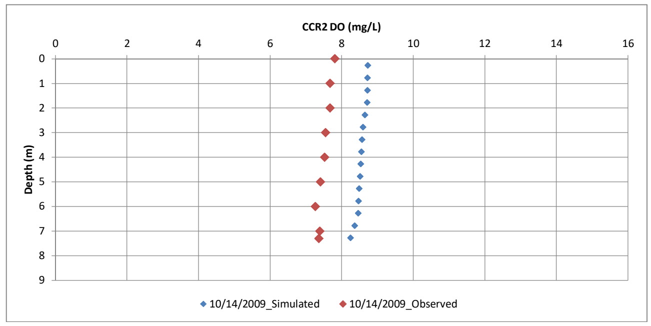

CCR3 DO (mg/L)
Depth (m)
Observed data is considered suspect
9/15/2009_Simulated
9/15/2009_Observed

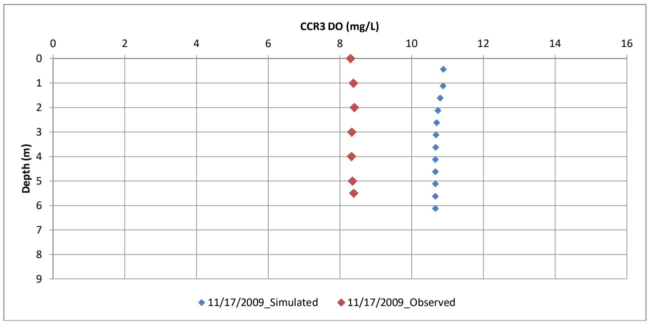

CCR2 DO (mg/L)
Depth (m)
Observed data is considered suspect
9/15/2009_Simulated
9/15/2009_Observed

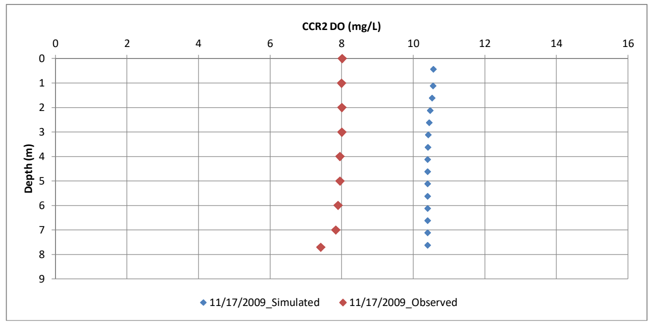

CCR3 DO (mg/L)
Depth (m)
Observed data is considered suspect
9/29/2009_Simulated
9/29/2009_Observed

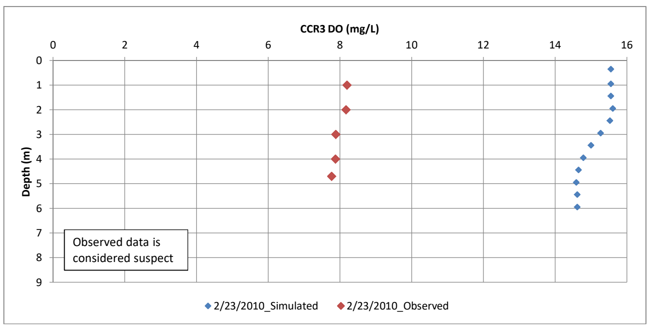

CCR2 DO (mg/L)
Depth (m)
Observed data is considered suspect
9/29/2009_Simulated
9/29/2009_Observed

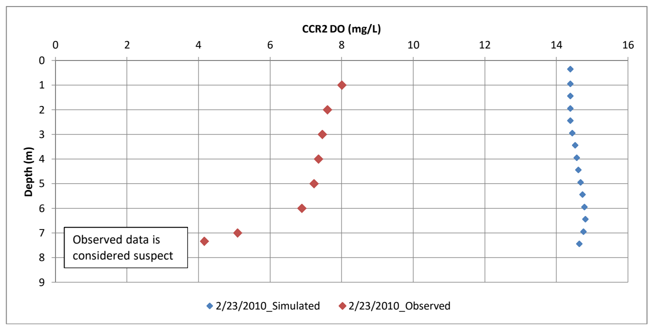

CCR3 DO (mg/L)
0 2 4 6 8 10 12 14 16
Depth (m)
0 1 2 3 4 5 6 7 8 9
10/14/2009_Simulated
10/14/2009_Observed

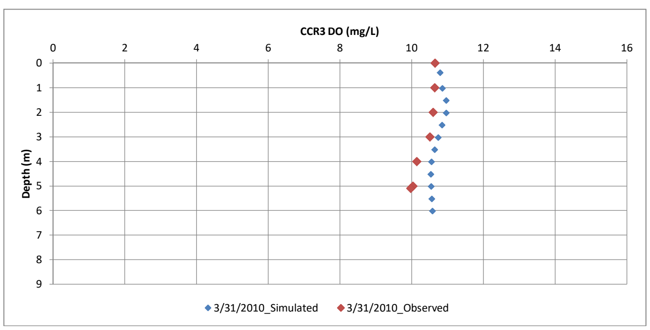

CCR2 DO (mg/L)
0 2 4 6 8 10 12 14 16
Depth (m)
0 1 2 3 4 5 6 7 8 9
10/14/2009_Simulated
10/14/2009_Observed

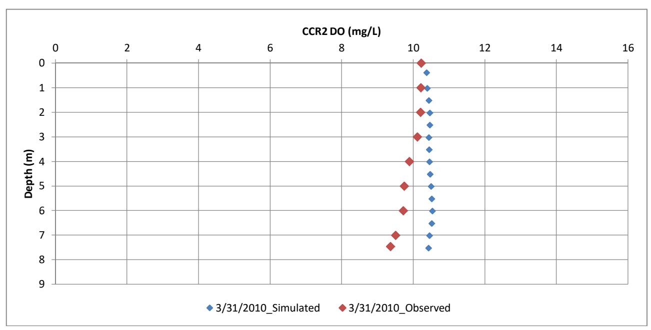

CCR3 DO (mg/L)
0 2 4 6 8 10 12 14 16
Depth (m)
0 1 2 3 4 5 6 7 8 9
11/17/2009_Simulated
11/17/2009_Observed

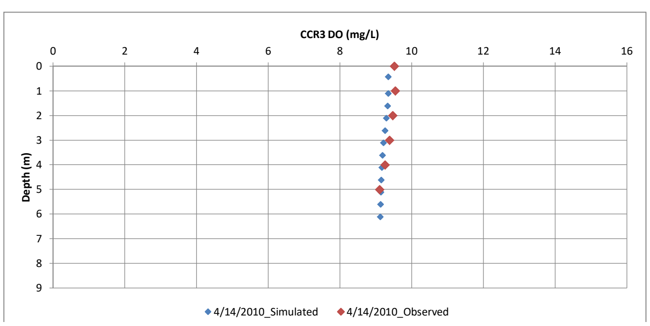

CCR2 DO (mg/L)
0 2 4 6 8 10 12 14 16
Depth (m)
0 1 2 3 4 5 6 7 8 9
11/17/2009_Simulated
11/17/2009_Observed

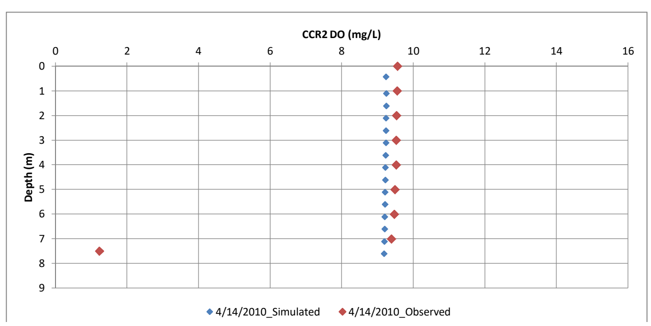

CCR3 DO (mg/L)
0 2 4 6 8 10 12 14 16
Depth (m)
0 1 2 3 4 5 6 7 8 9
Observed data is considered suspect
2/23/2010_Simulated
2/23/2010_Observed

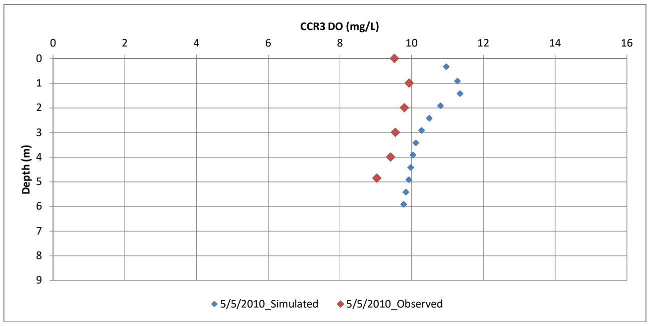

CCR2 DO (mg/L)
0 2 4 6 8 10 12 14 16
Depth (m)
0 1 2 3 4 5 6 7 8 9
Observed data is considered suspect
2/23/2010_Simulated
2/23/2010_Observed

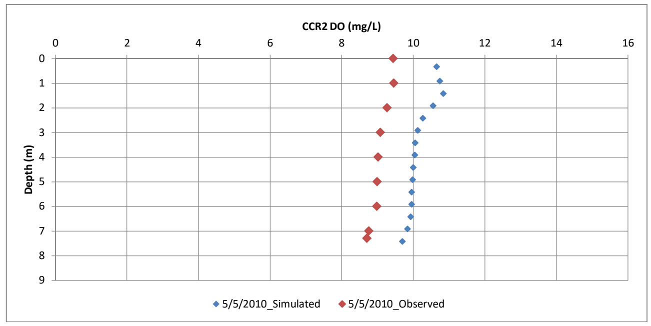

CCR3 DO (mg/L)
0 2 4 6 8 10 12 14 16
Depth (m)
0 1 2 3 4 5 6 7 8 9
3/31/2010_Simulated
3/31/2010_Observed

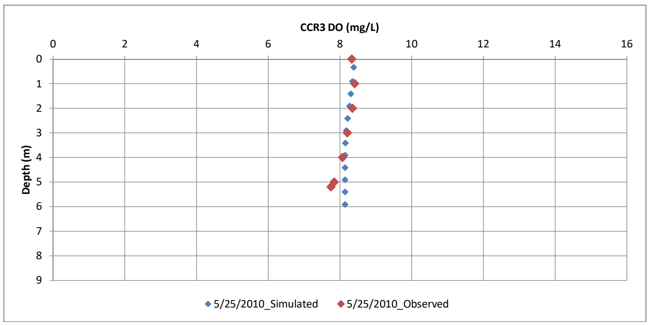

CCR2 DO (mg/L)
0 2 4 6 8 10 12 14 16
Depth (m)
0 1 2 3 4 5 6 7 8 9
3/31/2010_Simulated
3/31/2010_Observed

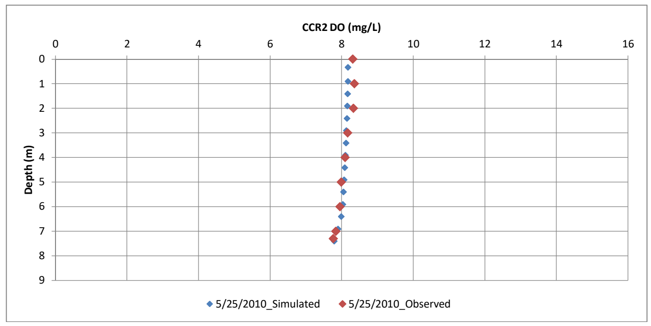

CCR3 DO (mg/L)
0 2 4 6 8 10 12 14 16
Depth (m)
0 1 2 3 4 5 6 7 8 9
4/14/2010_Simulated
4/14/2010_Observed

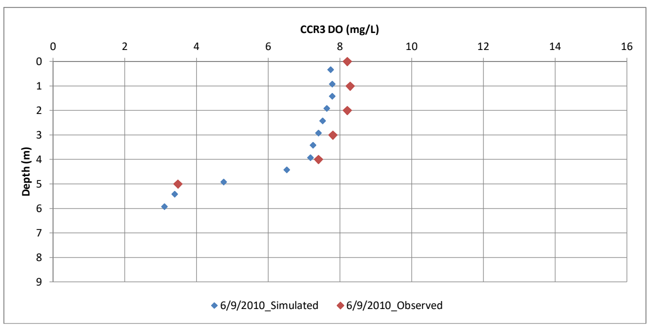

CCR2 DO (mg/L)
0 2 4 6 8 10 12 14 16
Depth (m)
0 1 2 3 4 5 6 7 8 9
4/14/2010_Simulated
4/14/2010_Observed

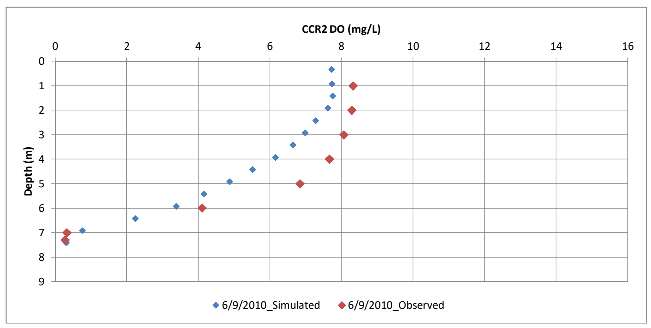

CCR3 DO (mg/L)
Depth (m)
5/5/2010_Simulated
5/5/2010_Observed

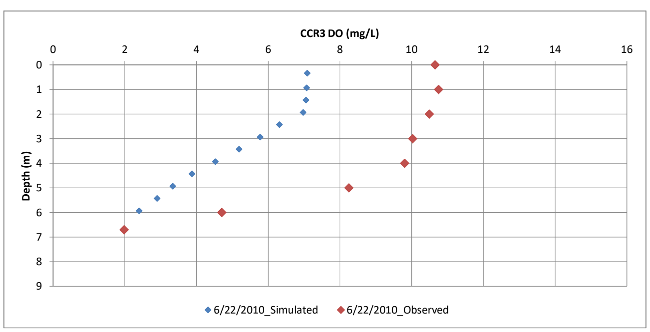

CCR2 DO (mg/L)
Depth (m)
5/5/2010_Simulated
5/5/2010_Observed

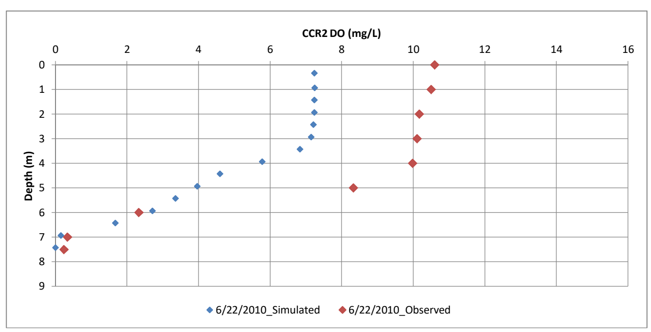

CCR3 DO (mg/L)
Depth (m)
5/25/2010_Simulated
5/25/2010_Observed

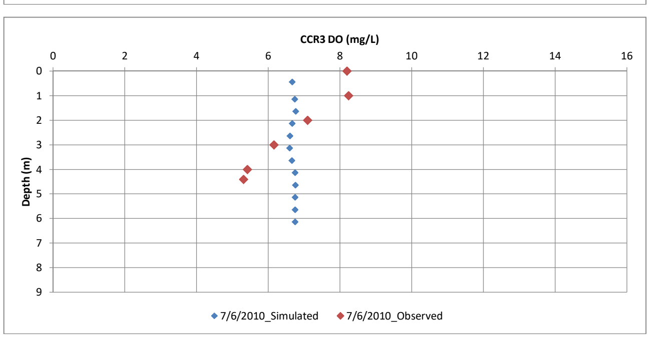

CCR2 DO (mg/L)
Depth (m)
5/25/2010_Simulated
5/25/2010_Observed

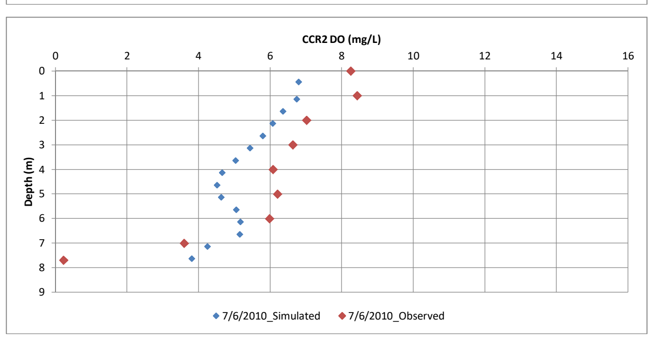

CCR3 DO (mg/L)
Depth (m)
6/9/2010_Simulated
6/9/2010_Observed

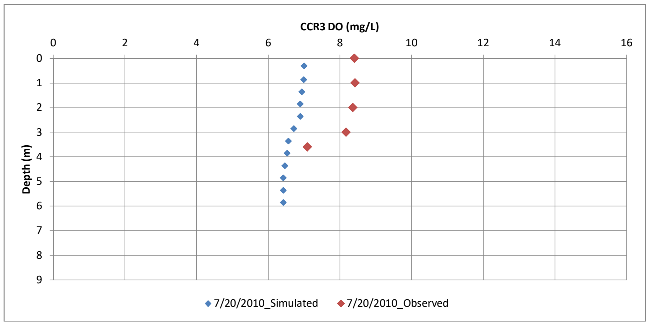

CCR2 DO (mg/L)
Depth (m)
6/9/2010_Simulated
6/9/2010_Observed

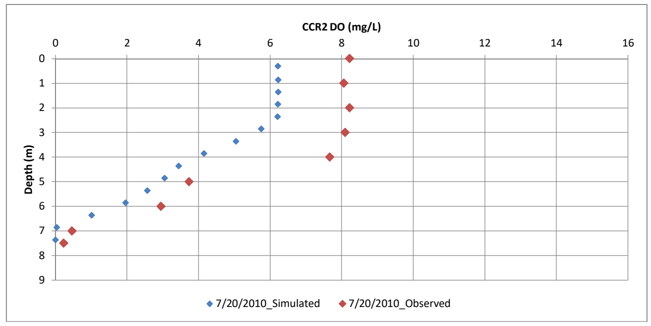

CCR3 DO (mg/L)
Depth (m)
6/22/2010_Simulated
6/22/2010_Observed

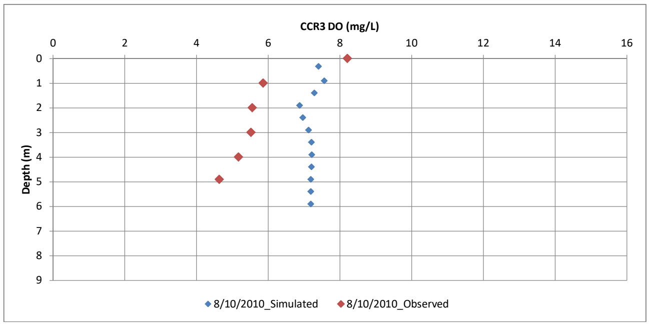

CCR2 DO (mg/L)
Depth (m)
6/22/2010_Simulated
6/22/2010_Observed

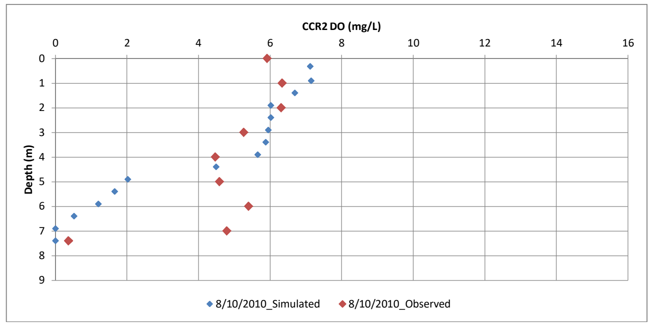

CCR3 DO (mg/L)
Depth (m)
7/6/2010_Simulated
7/6/2010_Observed

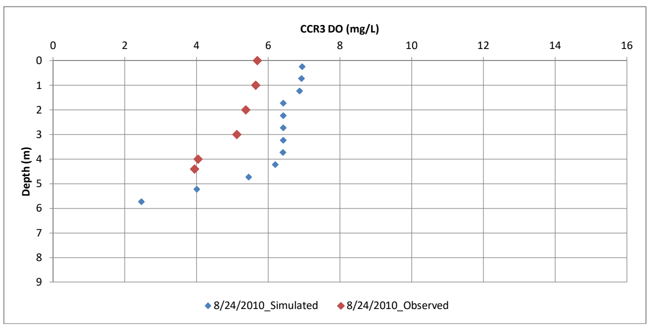

CCR2 DO (mg/L)
Depth (m)
7/6/2010_Simulated
7/6/2010_Observed

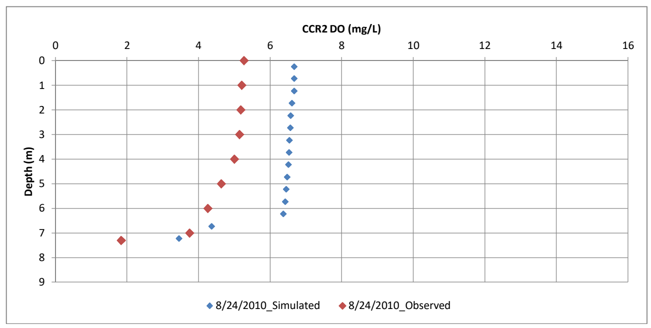

CCR3 DO (mg/L)
Depth (m)
7/20/2010_Simulated
7/20/2010_Observed

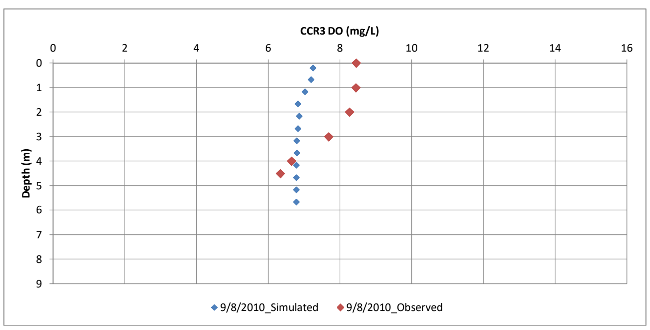

CCR2 DO (mg/L)
Depth (m)
7/20/2010_Simulated
7/20/2010_Observed

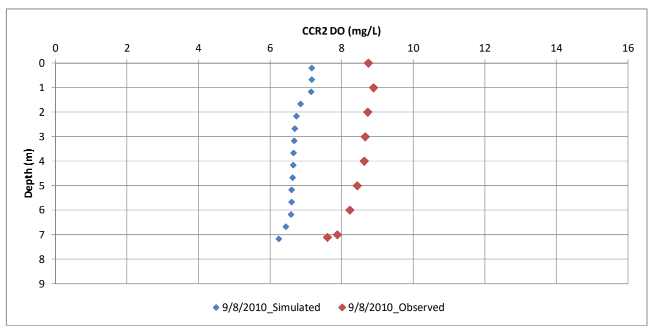

CCR3 DO (mg/L)
Depth (m)
8/10/2010_Simulated
8/10/2010_Observed

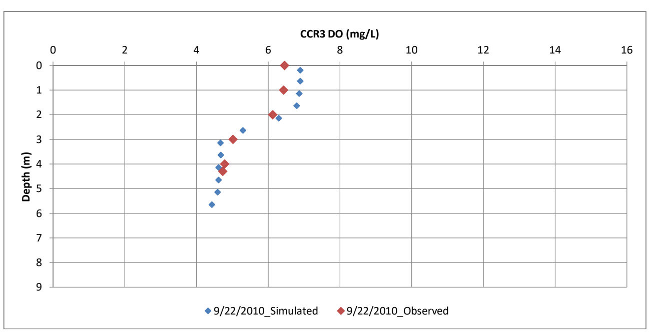

CCR2 DO (mg/L)
Depth (m)
8/10/2010_Simulated
8/10/2010_Observed

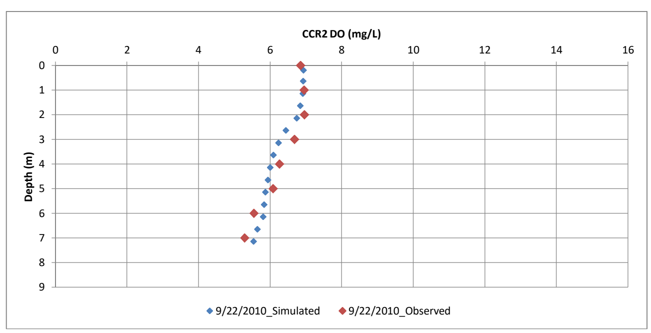

CCR3 DO (mg/L)
Depth (m)
8/24/2010_Simulated
8/24/2010_Observed

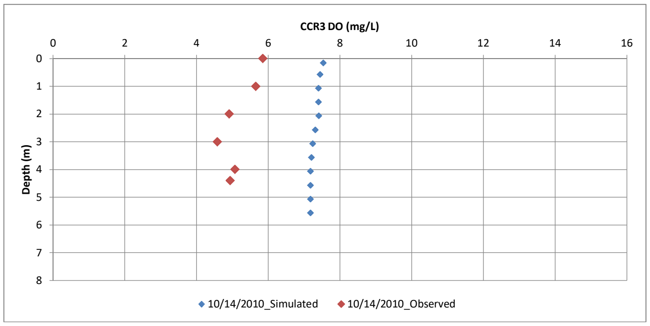

CCR2 DO (mg/L)
Depth (m)
8/24/2010_Simulated
8/24/2010_Observed

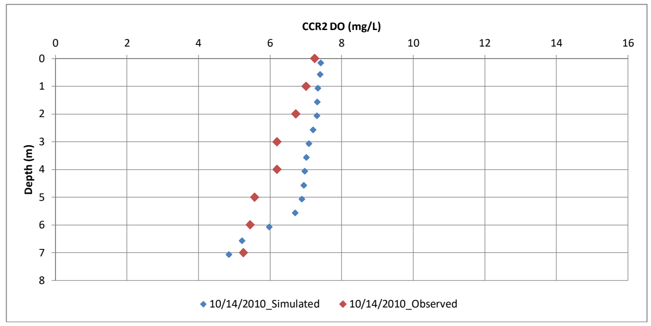

CCR3 DO (mg/L)
Depth (m)
9/8/2010_Simulated
9/8/2010_Observed

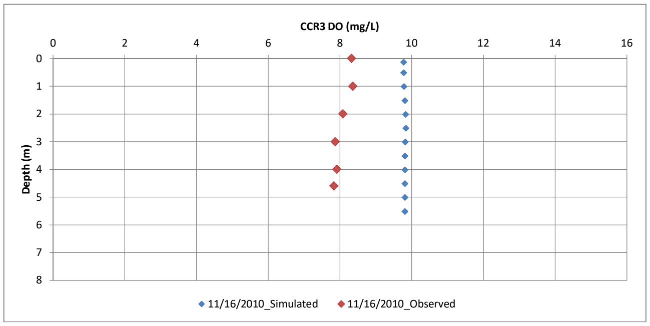

CCR2 DO (mg/L)
Depth (m)
9/8/2010_Simulated
9/8/2010_Observed

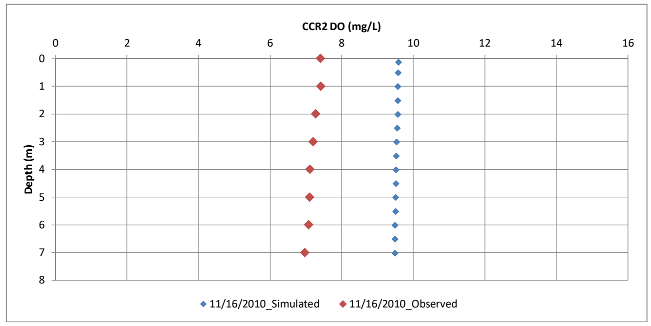

CCR3 DO (mg/L)
Depth (m)
9/22/2010_Simulated
9/22/2010_Observed

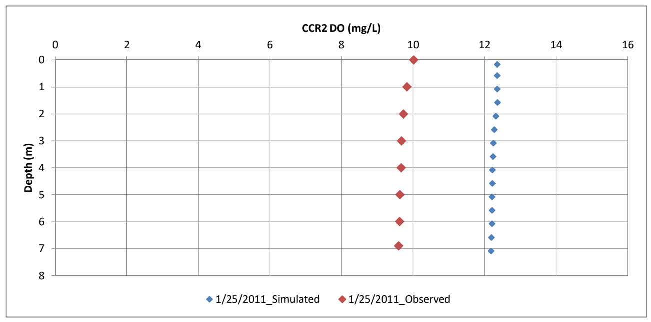

CCR2 DO (mg/L)
Depth (m)
9/22/2010_Simulated
9/22/2010_Observed


CCR3 DO (mg/L)
Depth (m)
10/14/2010_Simulated
10/14/2010_Observed

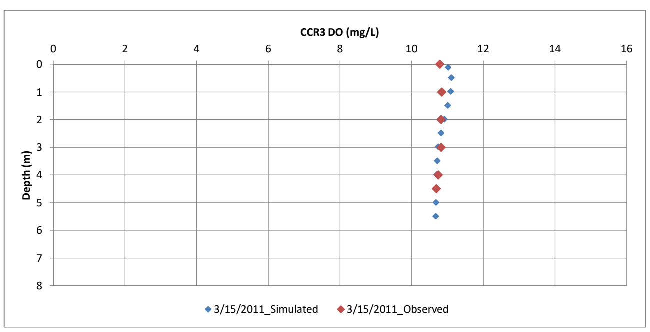

CCR2 DO (mg/L)
Depth (m)
10/14/2010_Simulated
10/14/2010_Observed

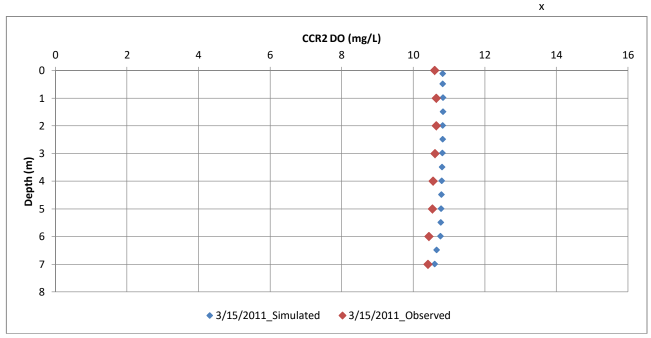

CCR3 DO (mg/L)
Depth (m)
11/16/2010_Simulated
11/16/2010_Observed

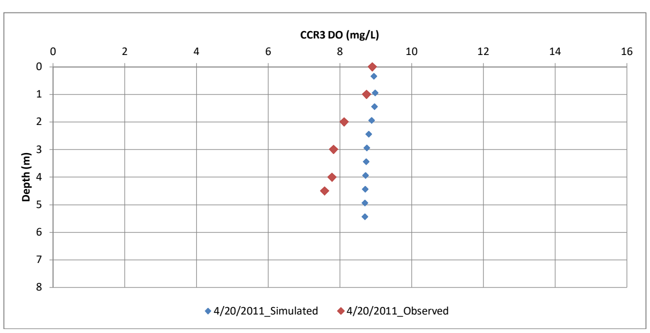

CCR2 DO (mg/L)
Depth (m)
11/16/2010_Simulated
11/16/2010_Observed

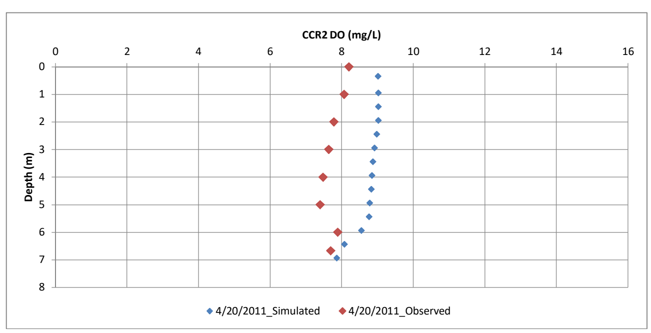

CCR2 DO (mg/L)
Depth (m)
1/25/2011_Simulated
1/25/2011_Observed

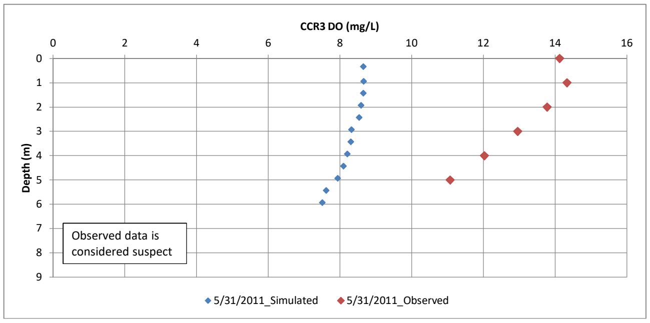
x

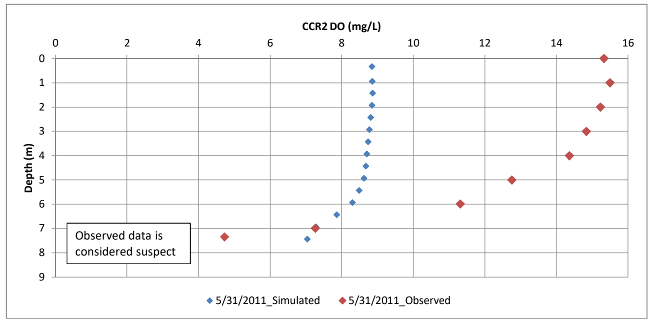

CCR3 DO (mg/L)
Depth (m)
3/15/2011_Simulated
3/15/2011_Observed

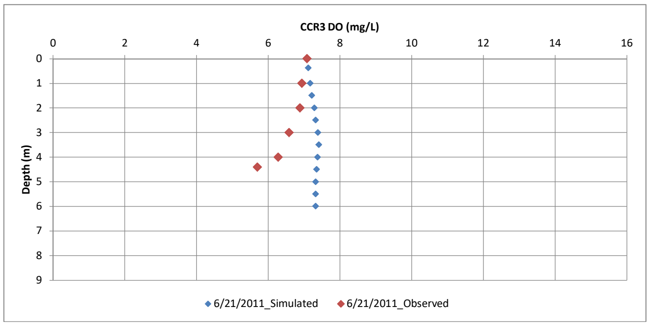

CCR2 DO (mg/L)
Depth (m)
3/15/2011_Simulated
3/15/2011_Observed

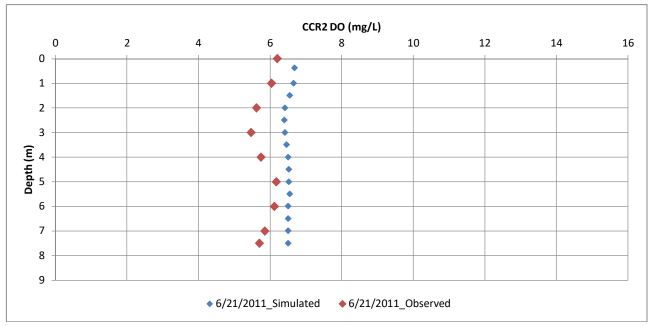

CCR3 DO (mg/L)
Depth (m)
4/20/2011_Simulated
4/20/2011_Observed

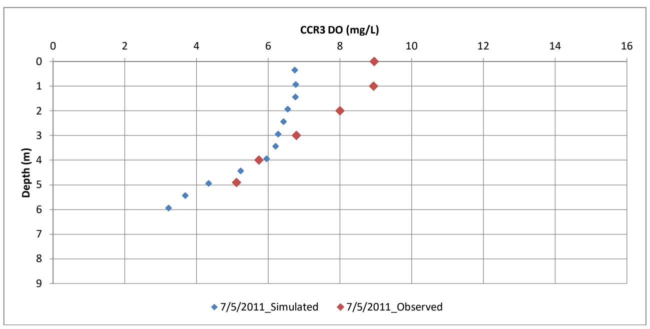

CCR2 DO (mg/L)
Depth (m)
4/20/2011_Simulated
4/20/2011_Observed

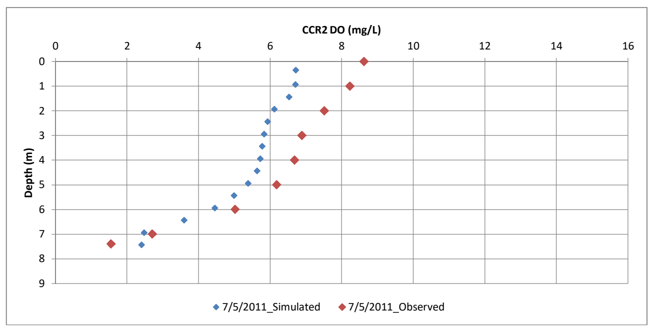

CCR3 DO (mg/L)
Depth (m)
Observed data is considered suspect
5/31/2011_Simulated
5/31/2011_Observed

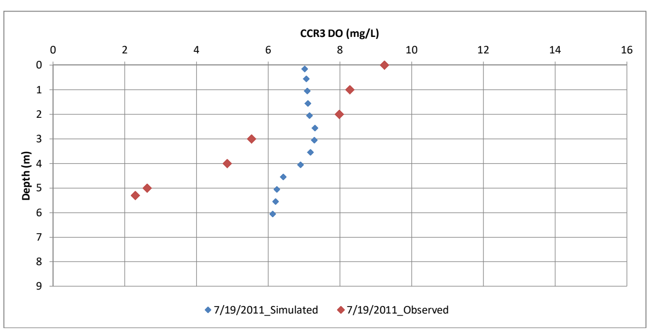

CCR2 DO (mg/L)
Depth (m)
Observed data is considered suspect
5/31/2011_Simulated
5/31/2011_Observed

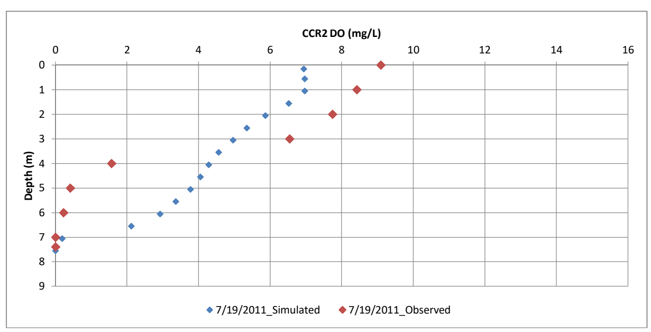

CCR3 DO (mg/L)
Depth (m)
6/21/2011_Simulated
6/21/2011_Observed

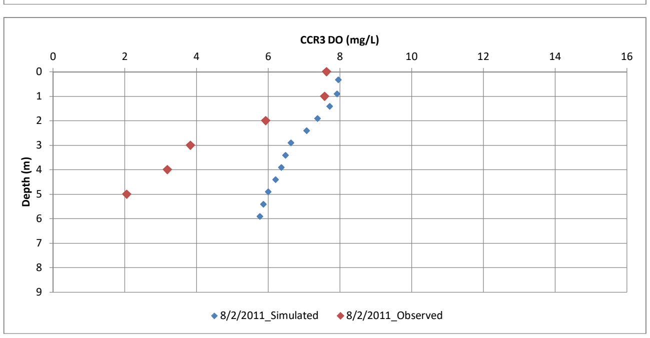

CCR2 DO (mg/L)
Depth (m)
6/21/2011_Simulated
6/21/2011_Observed

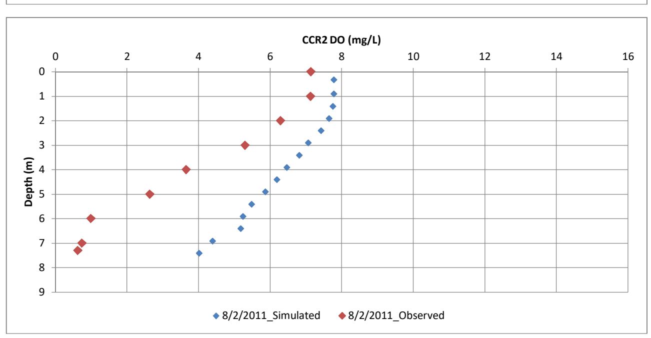

CCR3 DO (mg/L)
Depth (m)
7/5/2011_Simulated
7/5/2011_Observed

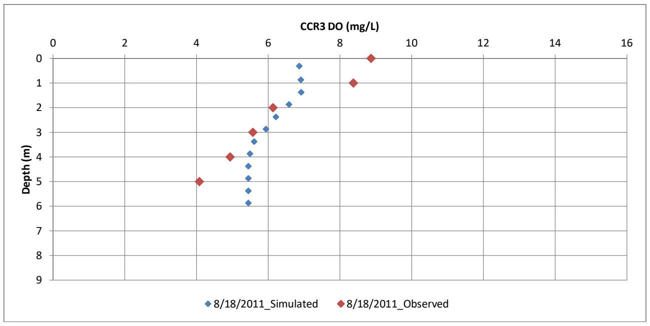

CCR2 DO (mg/L)
Depth (m)
7/5/2011_Simulated
7/5/2011_Observed

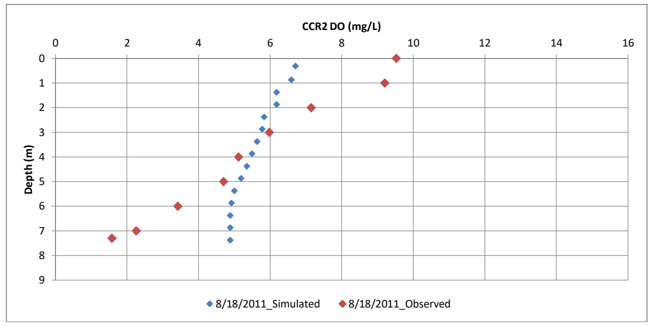

CCR3 DO (mg/L)
Depth (m)
7/19/2011_Simulated
7/19/2011_Observed

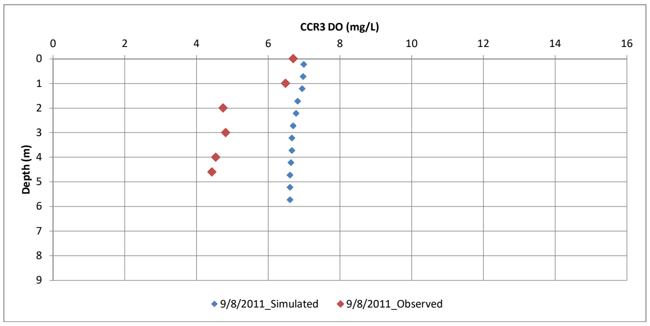

CCR2 DO (mg/L)
Depth (m)
7/19/2011_Simulated
7/19/2011_Observed

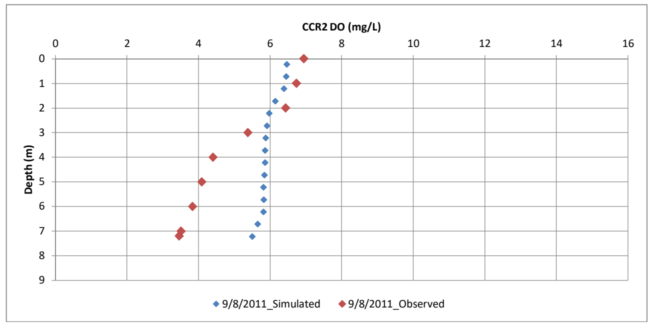

CCR3 DO (mg/L)
Depth (m)
8/2/2011_Simulated
8/2/2011_Observed

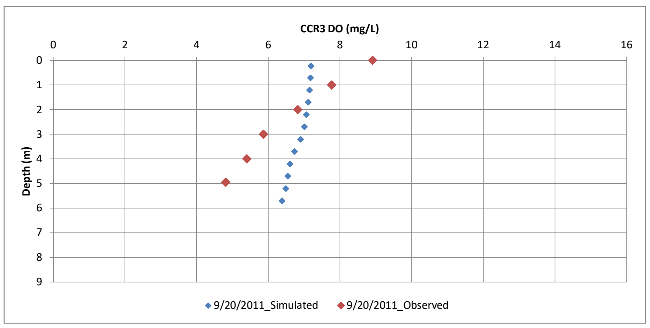

CCR2 DO (mg/L)
Depth (m)
8/2/2011_Simulated
8/2/2011_Observed

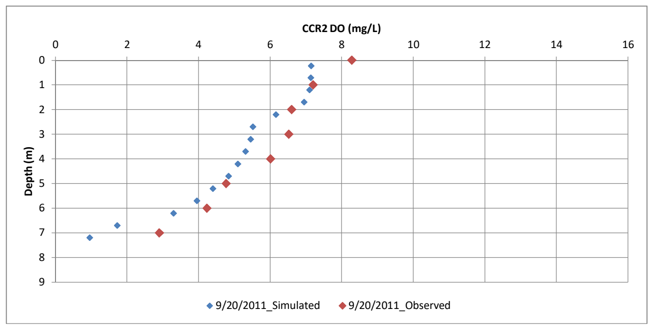

CCR3 DO (mg/L)
Depth (m)
8/18/2011_Simulated
8/18/2011_Observed

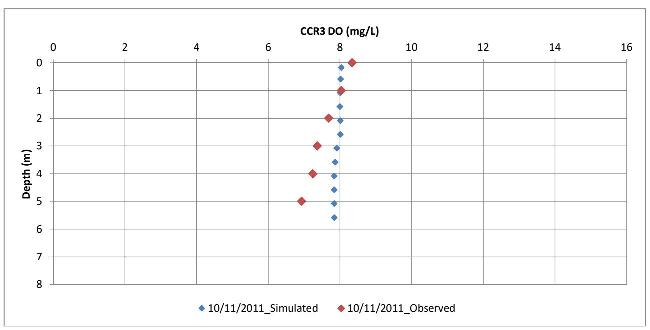

CCR2 DO (mg/L)
Depth (m)
8/18/2011_Simulated
8/18/2011_Observed

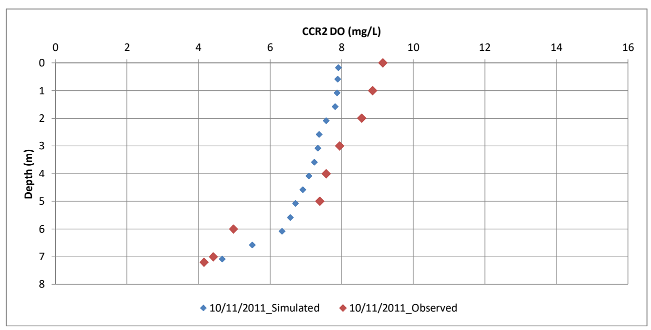

CCR3 DO (mg/L)
Depth (m)
9/8/2011_Simulated
9/8/2011_Observed

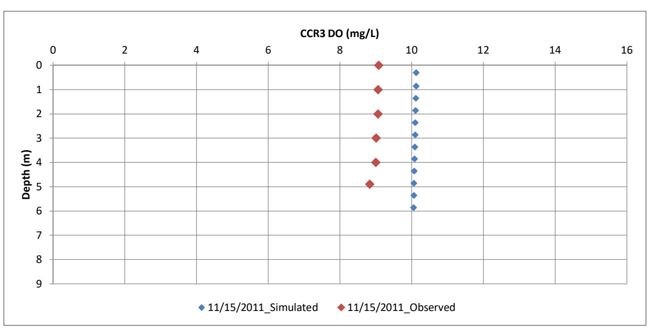

CCR2 DO (mg/L)
Depth (m)
9/8/2011_Simulated
9/8/2011_Observed

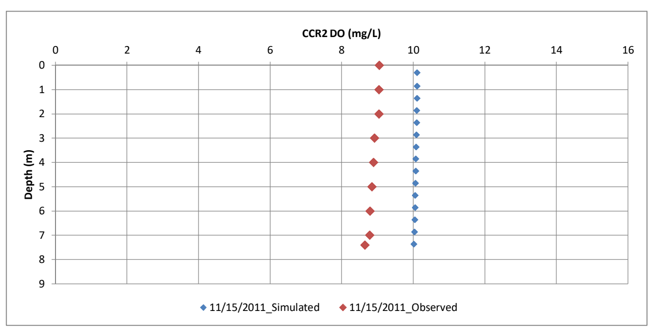

CCR3 DO (mg/L)
Depth (m)
9/20/2011_Simulated
9/20/2011_Observed

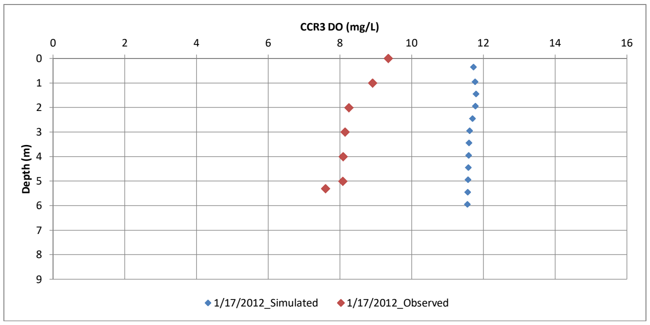

CCR2 DO (mg/L)
Depth (m)
9/20/2011_Simulated
9/20/2011_Observed

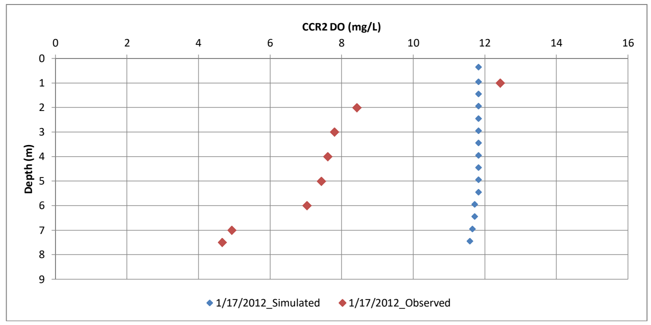

CCR3 DO (mg/L)
Depth (m)
10/11/2011_Simulated
10/11/2011_Observed

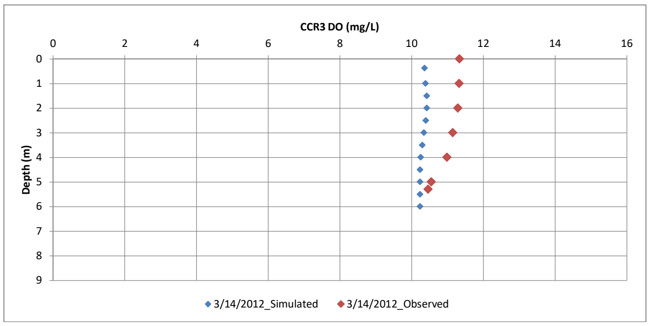

CCR2 DO (mg/L)
Depth (m)
10/11/2011_Simulated
10/11/2011_Observed

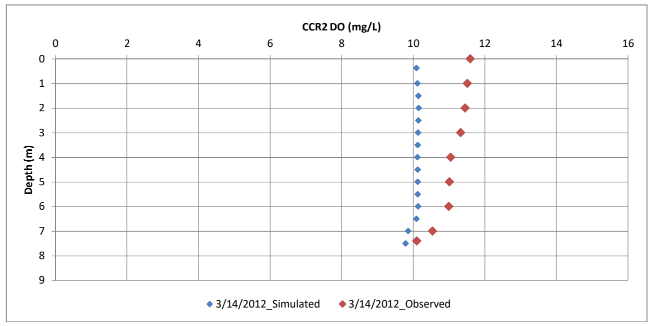

CCR3 DO (mg/L)
Depth (m)
11/15/2011_Simulated
11/15/2011_Observed

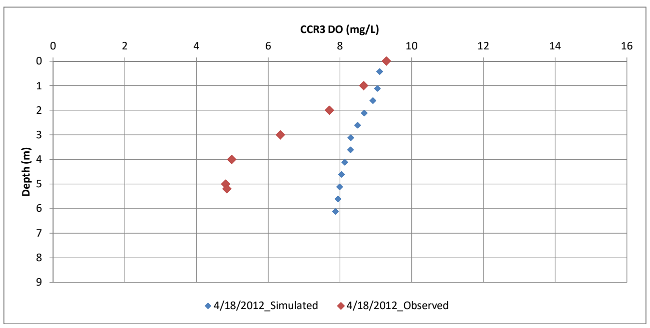

CCR2 DO (mg/L)
Depth (m)
11/15/2011_Simulated
11/15/2011_Observed

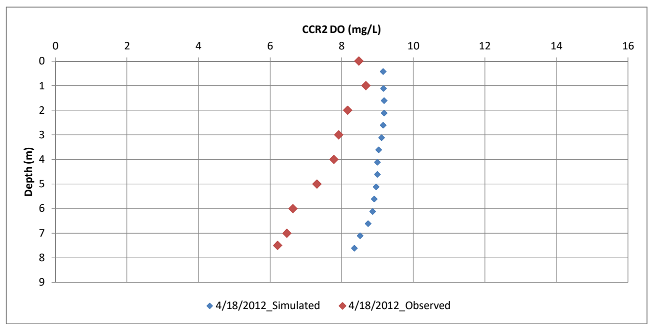

CCR3 DO (mg/L)
Depth (m)
1/17/2012_Simulated
1/17/2012_Observed

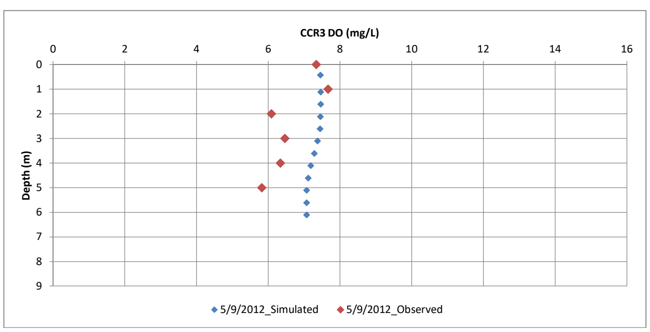

CCR2 DO (mg/L)
Depth (m)
1/17/2012_Simulated
1/17/2012_Observed

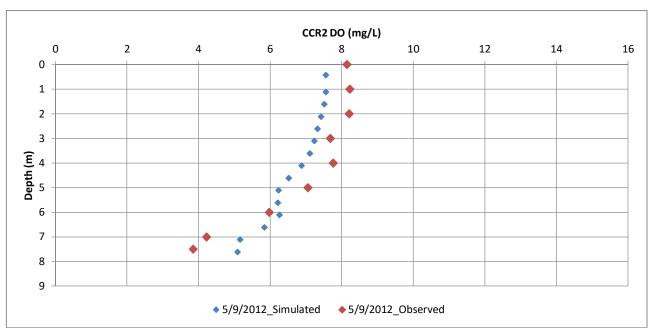

CCR3 DO (mg/L)
Depth (m)
3/14/2012_Simulated
3/14/2012_Observed

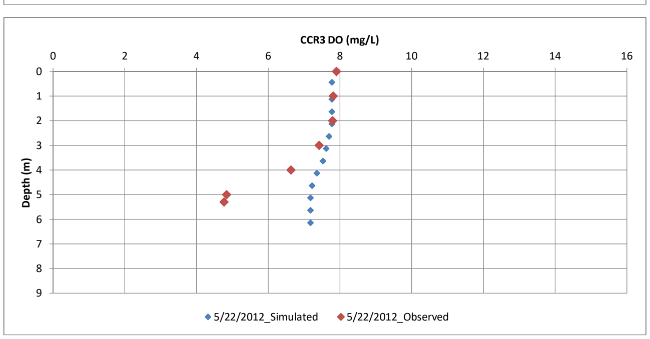

CCR2 DO (mg/L)
Depth (m)
3/14/2012_Simulated
3/14/2012_Observed

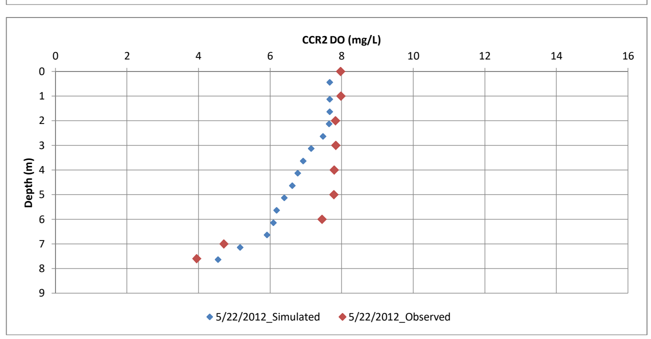

CCR3 DO (mg/L)
Depth (m)
4/18/2012_Simulated
4/18/2012_Observed

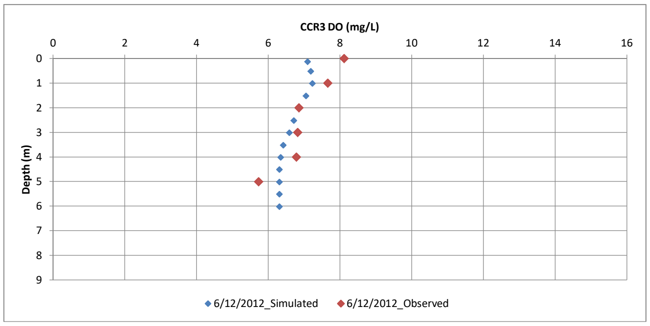

CCR2 DO (mg/L)
Depth (m)
4/18/2012_Simulated
4/18/2012_Observed

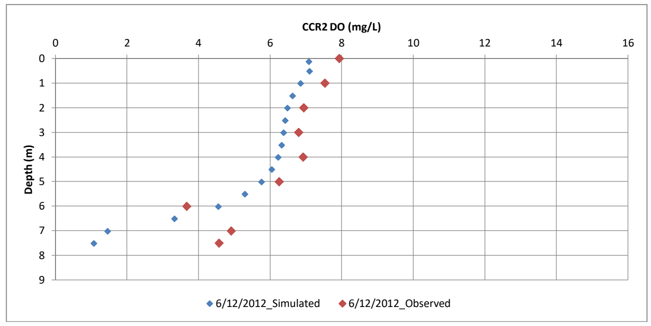

CCR3 DO (mg/L)
Depth (m)
5/9/2012_Simulated
5/9/2012_Observed

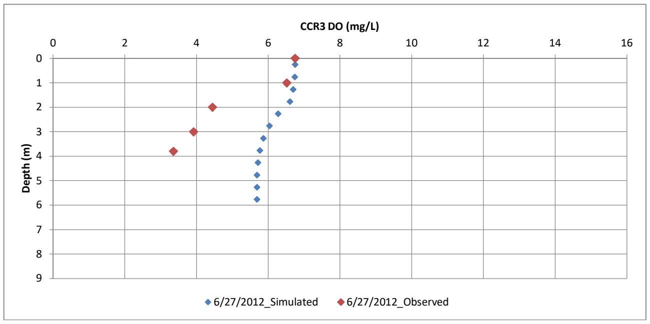

CCR2 DO (mg/L)
Depth (m)
5/9/2012_Simulated
5/9/2012_Observed

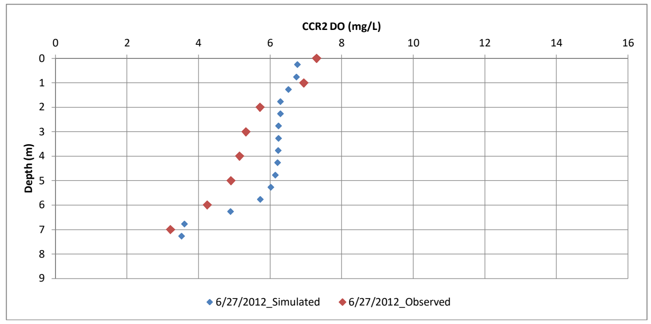

CCR3 DO (mg/L)
Depth (m)
5/22/2012_Simulated
5/22/2012_Observed

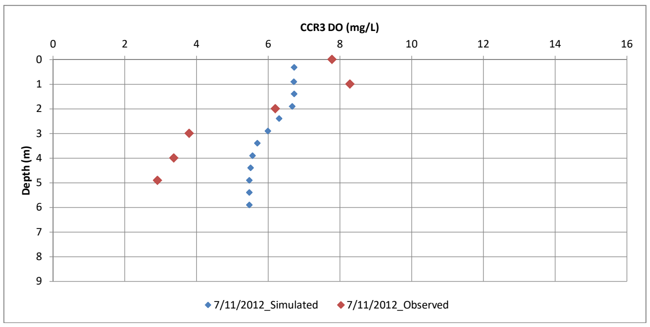

CCR2 DO (mg/L)
Depth (m)
5/22/2012_Simulated
5/22/2012_Observed

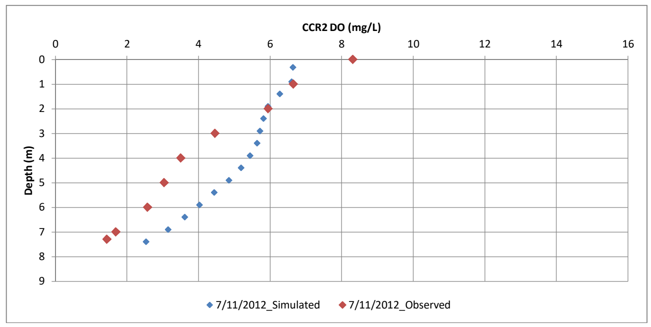

CCR3 DO (mg/L)
Depth (m)
6/12/2012_Simulated
6/12/2012_Observed

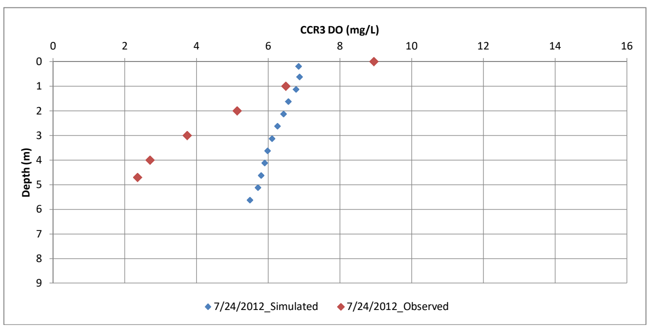

CCR2 DO (mg/L)
Depth (m)
6/12/2012_Simulated
6/12/2012_Observed

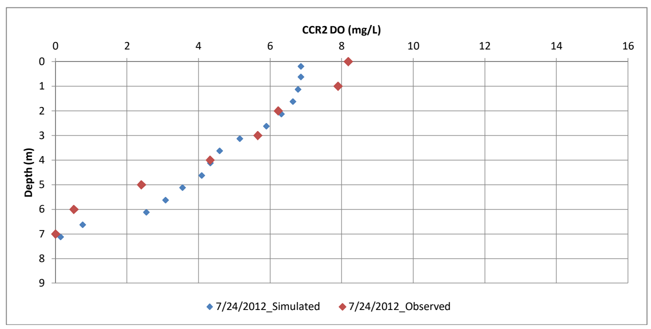

CCR3 DO (mg/L)
Depth (m)
6/27/2012_Simulated
6/27/2012_Observed

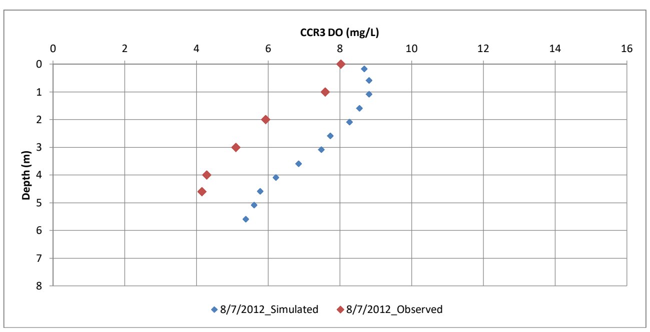

CCR2 DO (mg/L)
Depth (m)
6/27/2012_Simulated
6/27/2012_Observed

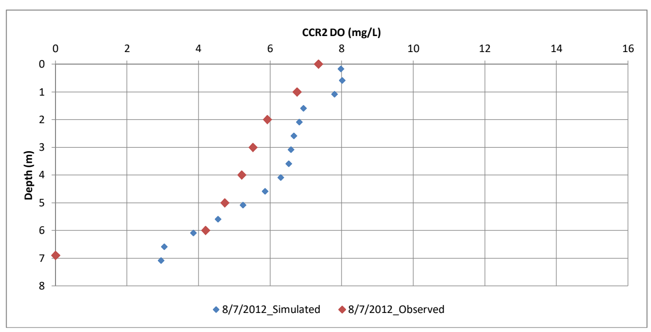

CCR3 DO (mg/L)
Depth (m)
7/11/2012_Simulated
7/11/2012_Observed

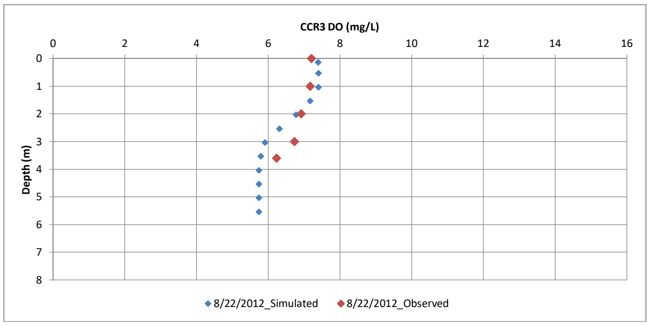

CCR2 DO (mg/L)
Depth (m)
7/11/2012_Simulated
7/11/2012_Observed

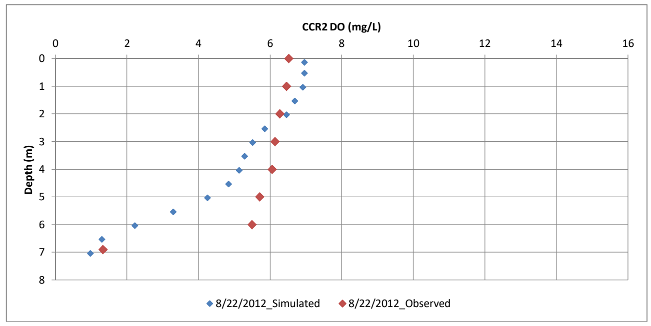

CCR3 DO (mg/L)
Depth (m)
7/24/2012_Simulated
7/24/2012_Observed


CCR2 DO (mg/L)
Depth (m)
7/24/2012_Simulated
7/24/2012_Observed


CCR3 DO (mg/L)
Depth (m)
8/7/2012_Simulated
8/7/2012_Observed


CCR2 DO (mg/L)
Depth (m)
8/7/2012_Simulated
8/7/2012_Observed


CCR3 DO (mg/L)
0 2 4 6 8 10 12 14 16
0 1 2 3 4 5 6 7 8
Depth (m)
8/22/2012_Simulated
8/22/2012_Observed


CCR2 DO (mg/L)
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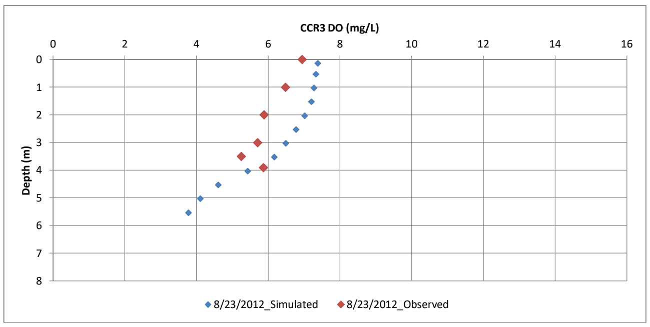
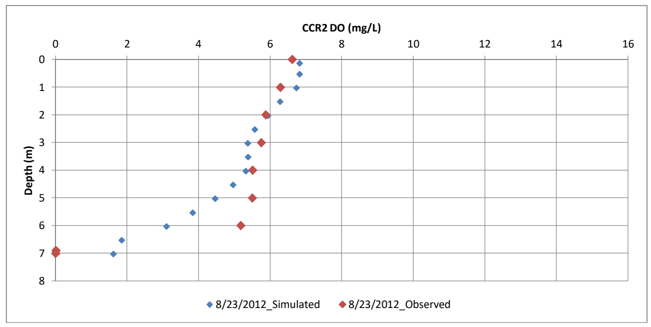
0 1 2 3 4 5 6 7 8
Depth (m)
8/22/2012_Simulated
8/22/2012_Observed

x


CCR3 DO (mg/L)
0 2 4 6 8 10 12 14 16
0 1 2 3 4 5 6 7 8
Depth (m)
8/23/2012_Simulated
8/23/2012_Observed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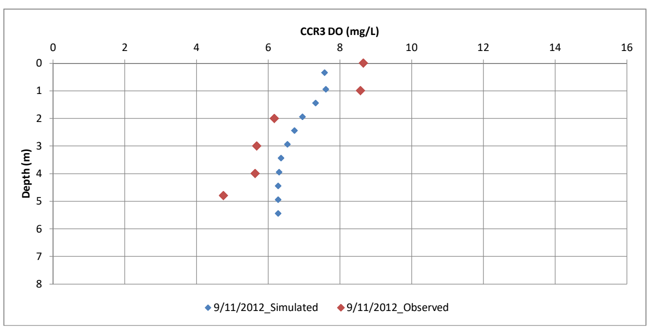
0 1 2 3 4 5 6 7 8
Depth (m)
8/23/2012_Simulated
8/23/2012_Observed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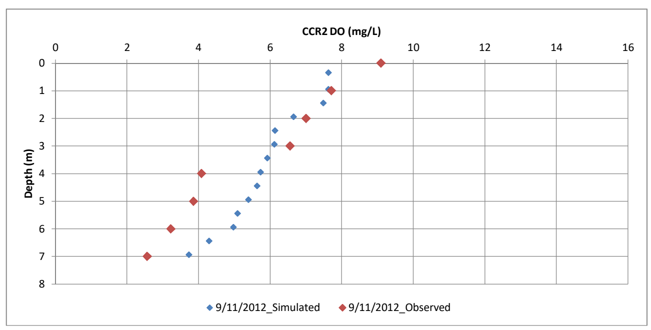
0 1 2 3 4 5 6 7 8
Depth (m)
9/11/2012_Simulated
9/11/2012_Observed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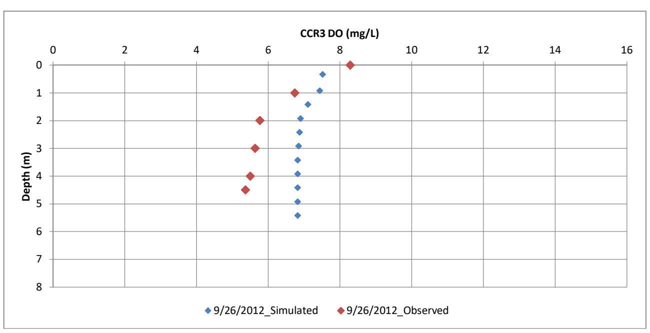
0 1 2 3 4 5 6 7 8
Depth (m)
9/11/2012_Simulated
9/11/2012_Observed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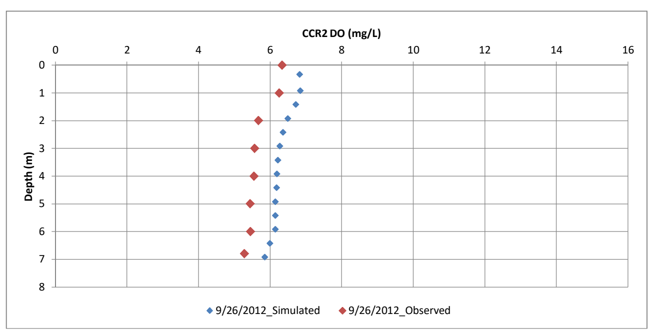
0 1 2 3 4 5 6 7 8
Depth (m)
9/26/2012_Simulated
9/26/2012_Observed


CCR2 DO (mg/L)
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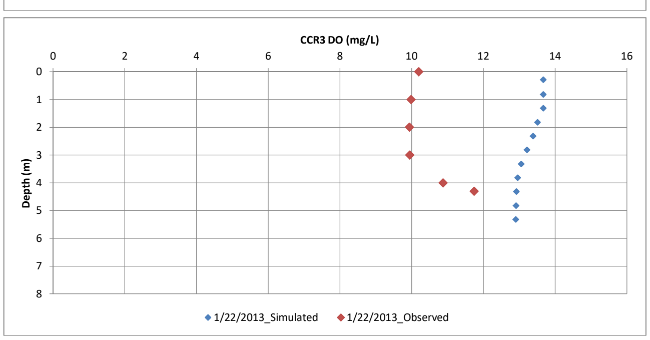
0 1 2 3 4 5 6 7 8
Depth (m)
9/26/2012_Simulated
9/26/2012_Observed


CCR3 DO (mg/L)
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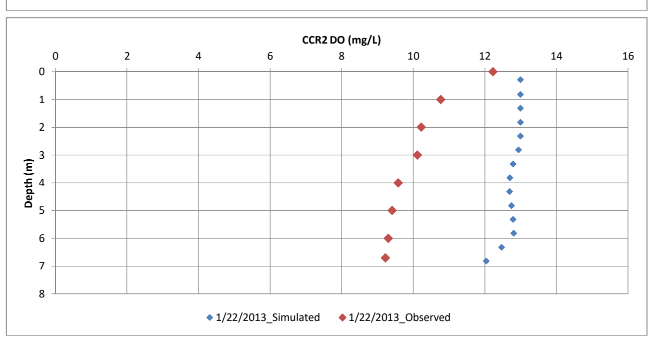
0 1 2 3 4 5 6 7 8
Depth (m)
1/22/2013_Simulated
1/22/2013_Observed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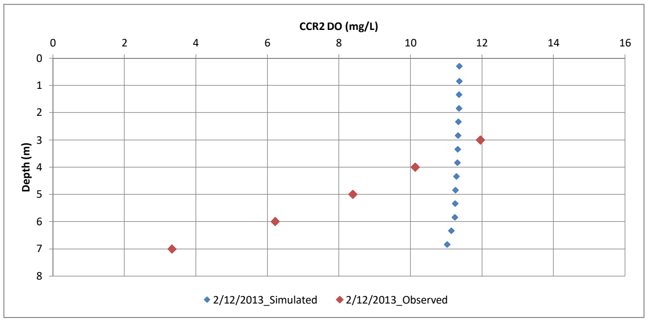
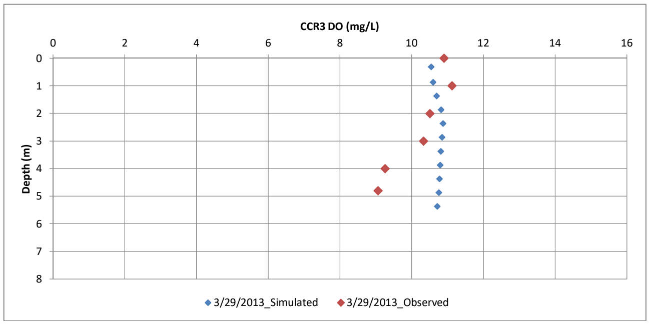
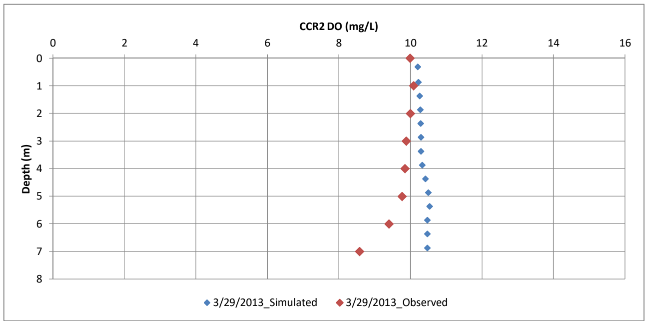
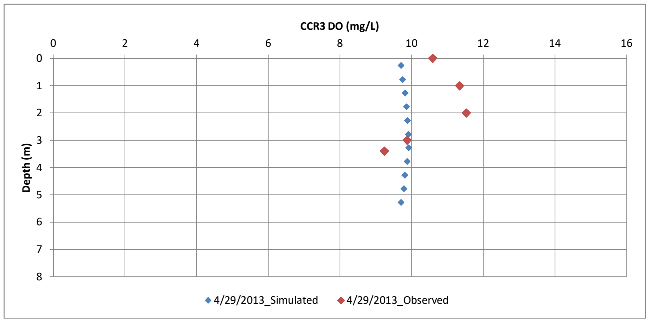
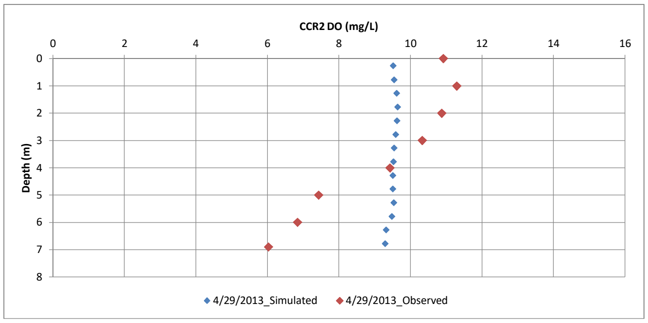
0 1 2 3 4 5 6 7 8
Depth (m)
1/22/2013_Simulated
1/22/2013_Observed

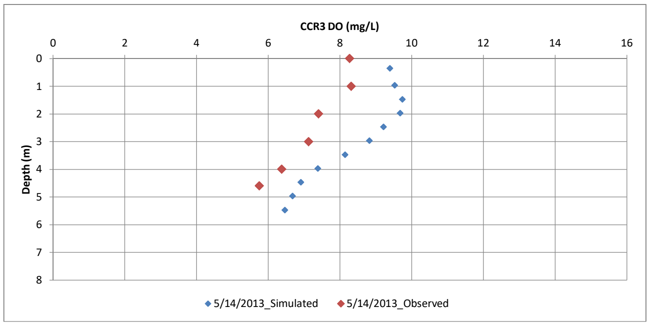

CCR2 DO (mg/L)
Depth (m)
2/12/2013_Simulated
2/12/2013_Observed

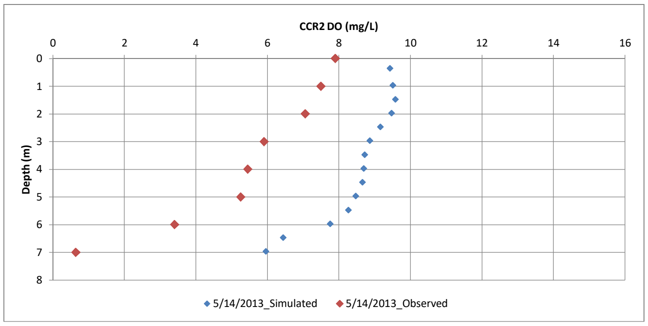

CCR3 DO (mg/L)
Depth (m)
3/29/2013_Simulated
3/29/2013_Observed

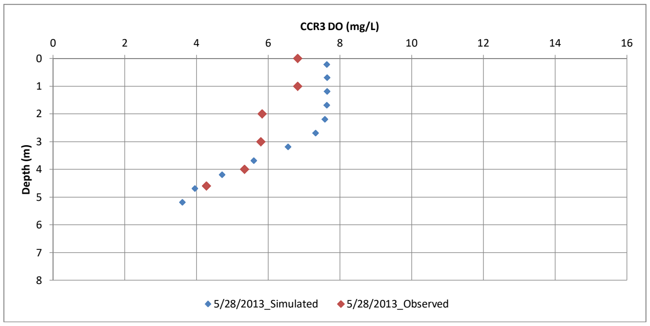

CCR2 DO (mg/L)
Depth (m)
3/29/2013_Simulated
3/29/2013_Observed

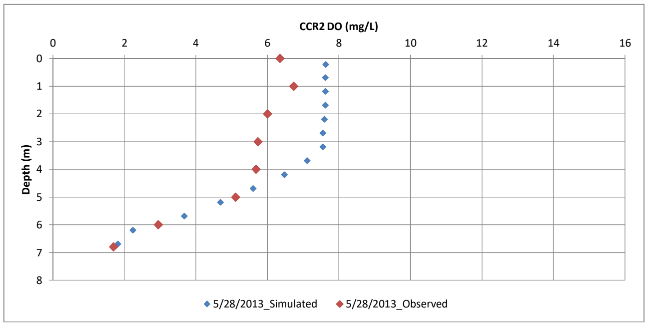

CCR3 DO (mg/L)
Depth (m)
4/29/2013_Simulated
4/29/2013_Observed

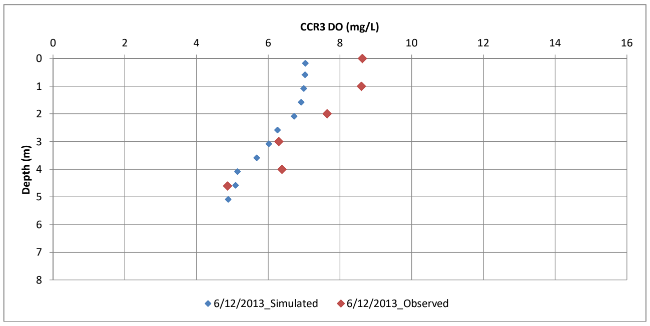

CCR2 DO (mg/L)
Depth (m)
4/29/2013_Simulated
4/29/2013_Observed

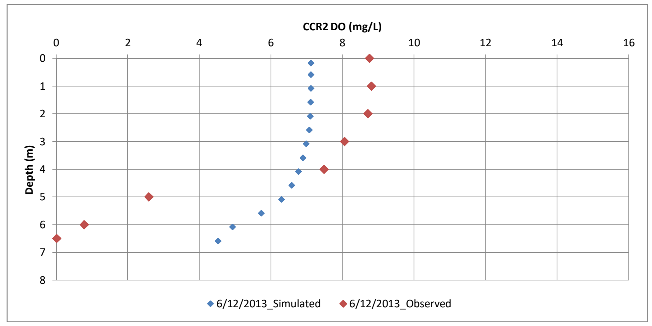

CCR3 DO (mg/L)
Depth (m)
5/14/2013_Simulated
5/14/2013_Observed

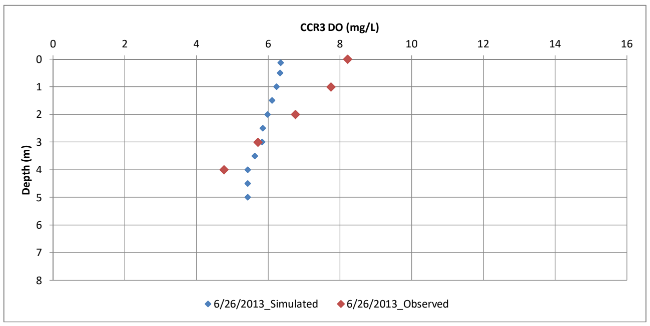

CCR2 DO (mg/L)
Depth (m)
5/14/2013_Simulated
5/14/2013_Observed

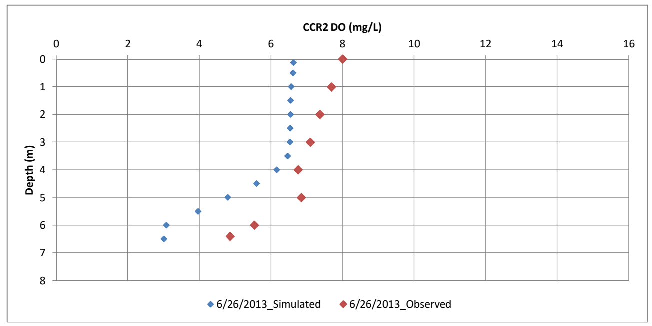

CCR3 DO (mg/L)
Depth (m)
5/28/2013_Simulated
5/28/2013_Observed

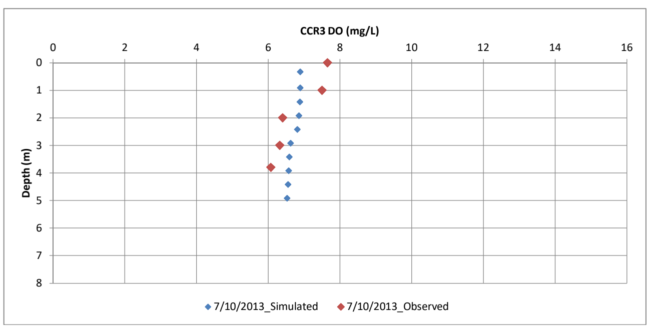

CCR2 DO (mg/L)
Depth (m)
5/28/2013_Simulated
5/28/2013_Observed

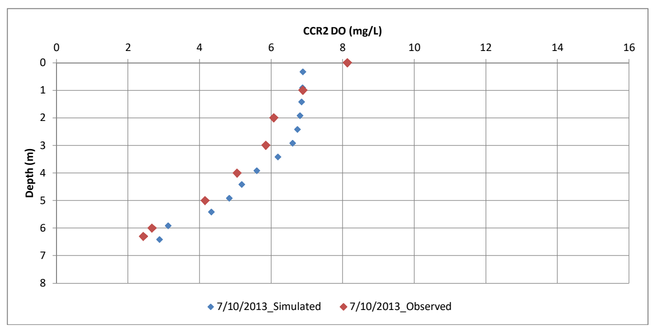

CCR3 DO (mg/L)
Depth (m)
6/12/2013_Simulated
6/12/2013_Observed

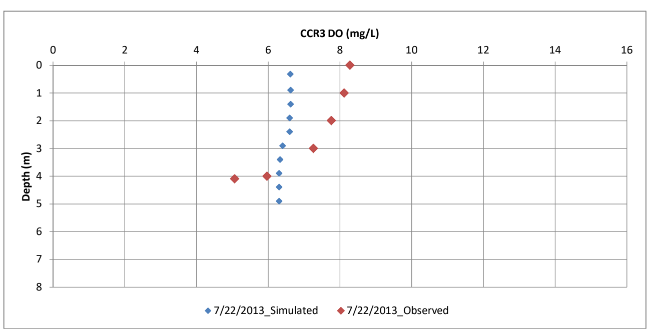

CCR2 DO (mg/L)
Depth (m)
6/12/2013_Simulated
6/12/2013_Observed

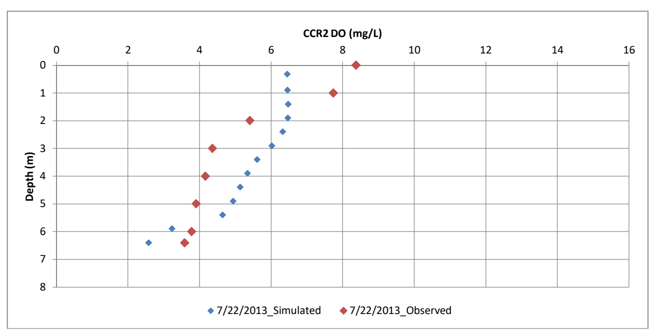

CCR3 DO (mg/L)
Depth (m)
6/26/2013_Simulated
6/26/2013_Observed

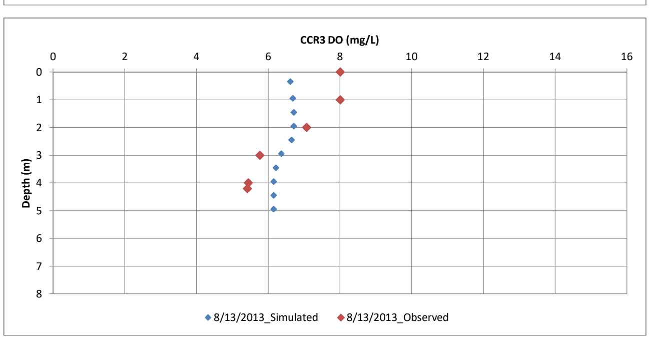

CCR2 DO (mg/L)
Depth (m)
6/26/2013_Simulated
6/26/2013_Observed

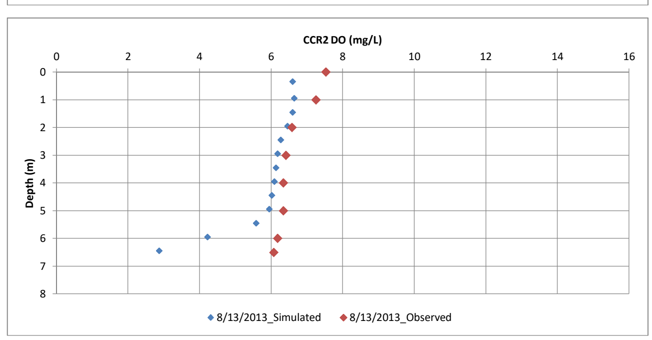

CCR3 DO (mg/L)
Depth (m)
7/10/2013_Simulated
7/10/2013_Observed

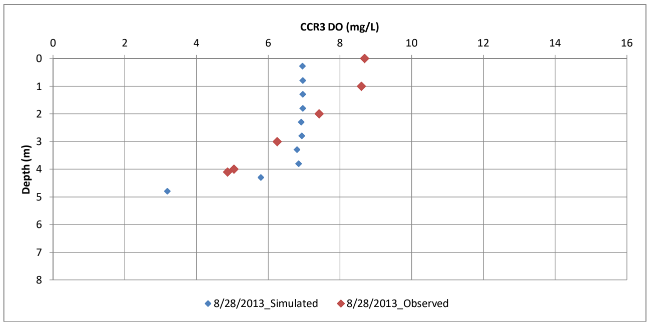

CCR2 DO (mg/L)
Depth (m)
7/10/2013_Simulated
7/10/2013_Observed

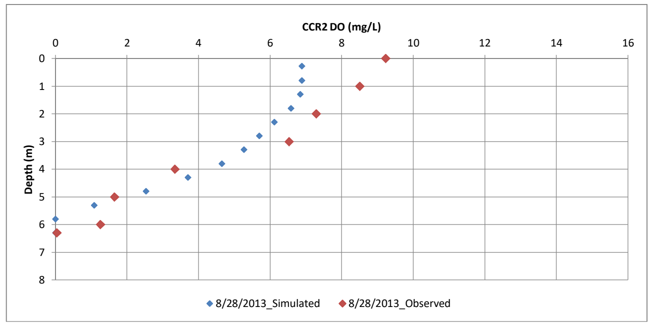

CCR3 DO (mg/L)
Depth (m)
7/22/2013_Simulated
7/22/2013_Observed

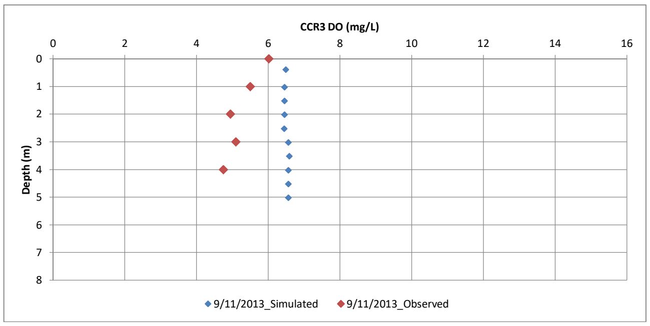

CCR2 DO (mg/L)
Depth (m)
7/22/2013_Simulated
7/22/2013_Observed

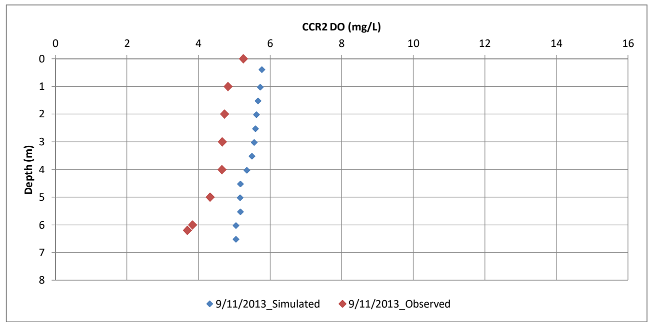

CCR3 DO (mg/L)
Depth (m)
8/13/2013_Simulated
8/13/2013_Observed

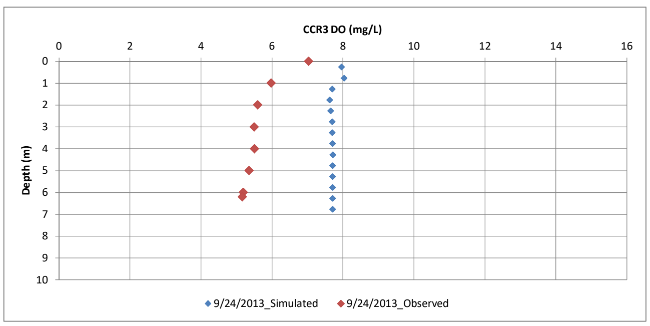

CCR2 DO (mg/L)
Depth (m)
8/13/2013_Simulated
8/13/2013_Observed

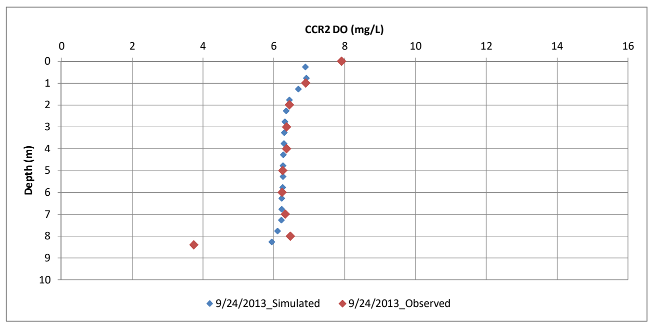

CCR3 DO (mg/L)
Depth (m)
8/28/2013_Simulated
8/28/2013_Observed

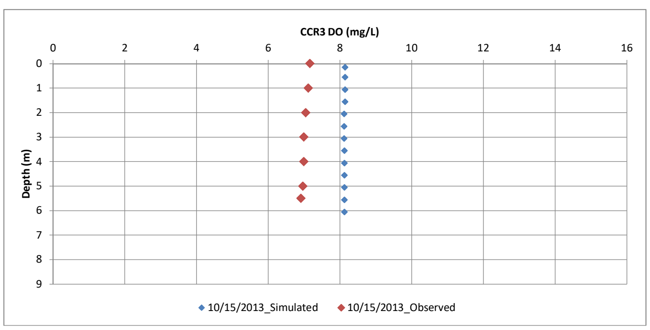

CCR2 DO (mg/L)
Depth (m)
8/28/2013_Simulated
8/28/2013_Observed

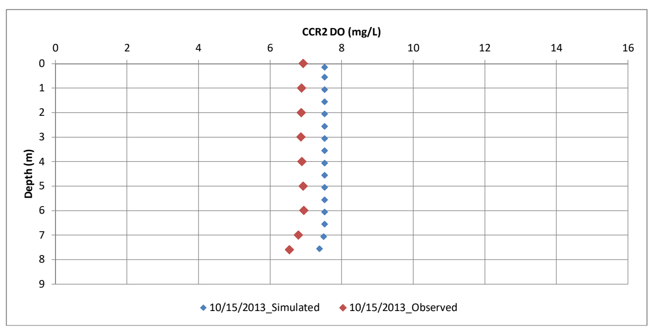

CCR3 DO (mg/L)
Depth (m)
9/11/2013_Simulated
9/11/2013_Observed

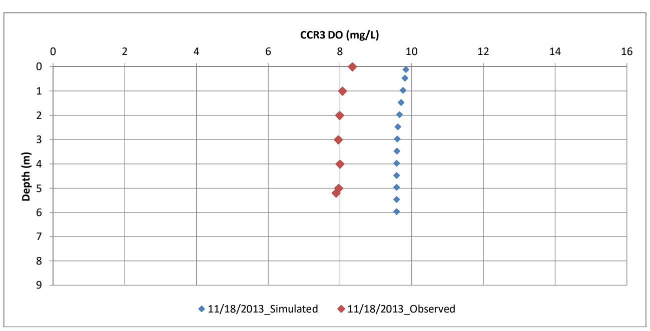

CCR2 DO (mg/L)
Depth (m)
9/11/2013_Simulated
9/11/2013_Observed

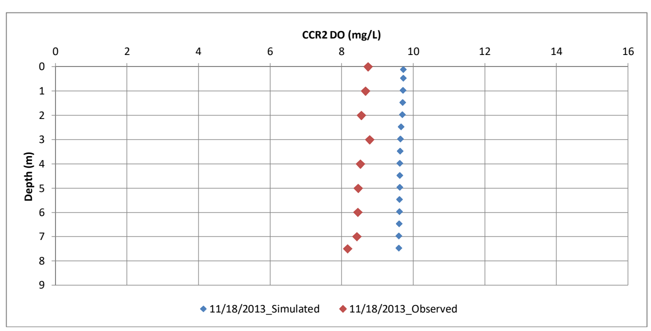

CCR3 DO (mg/L)
Depth (m)
9/24/2013_Simulated
9/24/2013_Observed


CCR2 DO (mg/L)
Depth (m)
9/24/2013_Simulated
9/24/2013_Observed


CCR3 DO (mg/L)
Depth (m)
10/15/2013_Simulated
10/15/2013_Observed

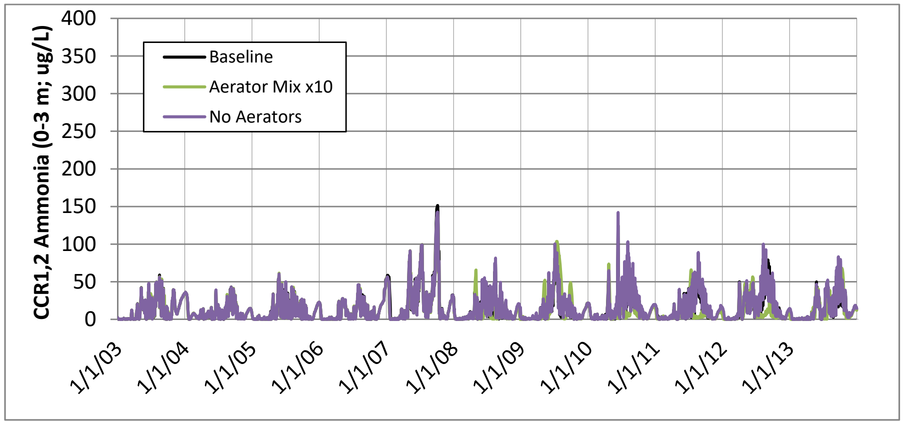

CCR2 DO (mg/L)
Depth (m)
10/15/2013_Simulated
10/15/2013_Observed

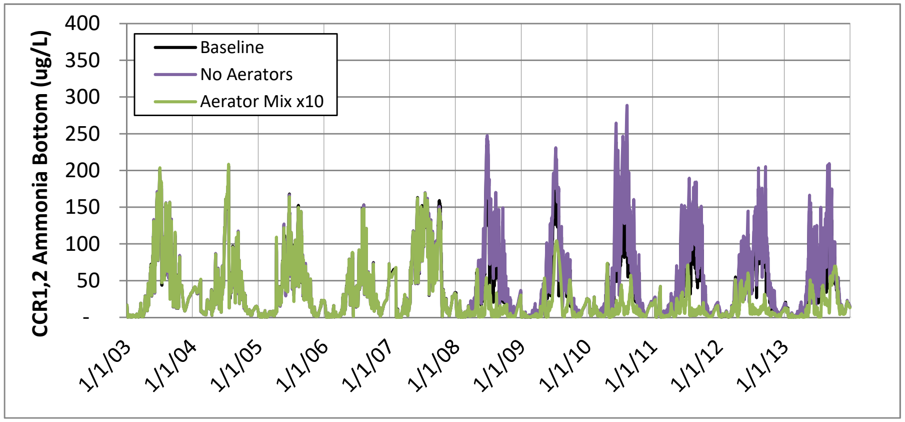

CCR3 DO (mg/L)
Depth (m)
11/18/2013_Simulated
11/18/2013_Observed

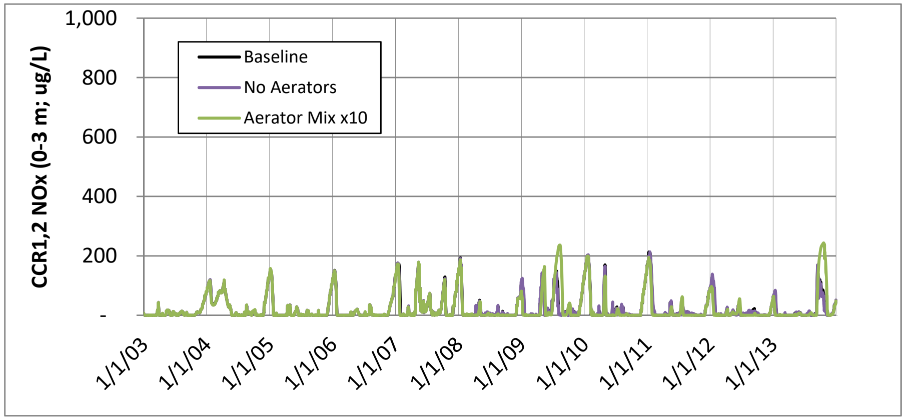

CCR2 DO (mg/L)
Depth (m)
11/18/2013_Simulated
11/18/2013_Observed

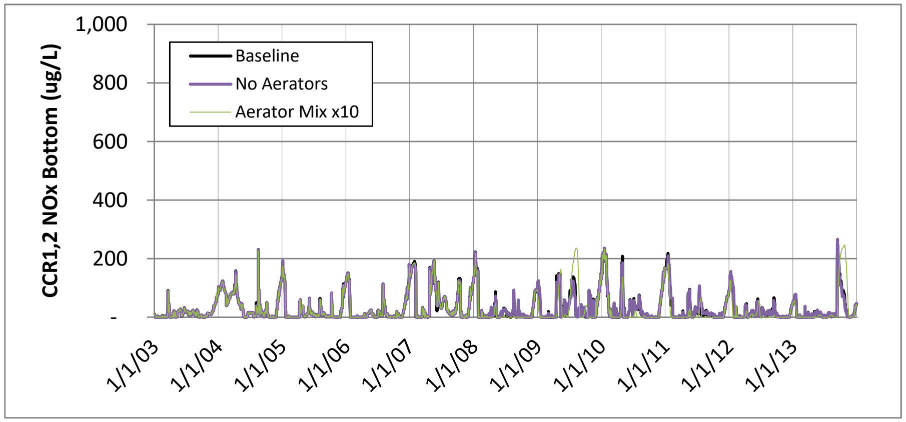
Attachment D: Sensitivity Analysis Results

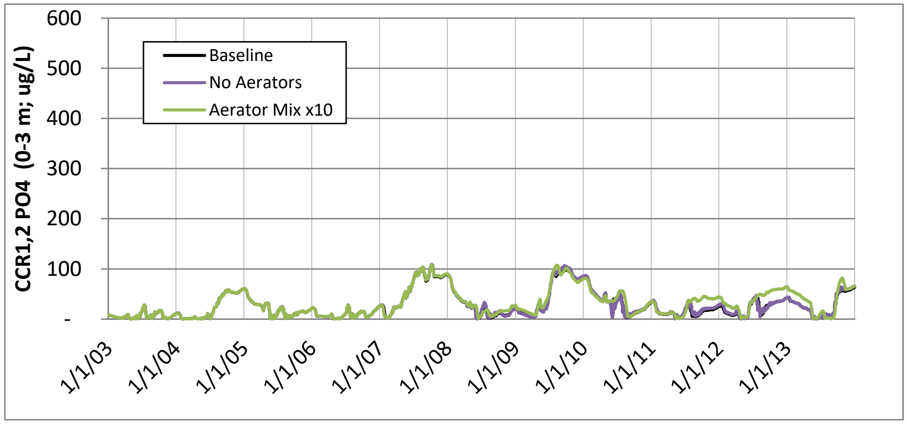
Contents

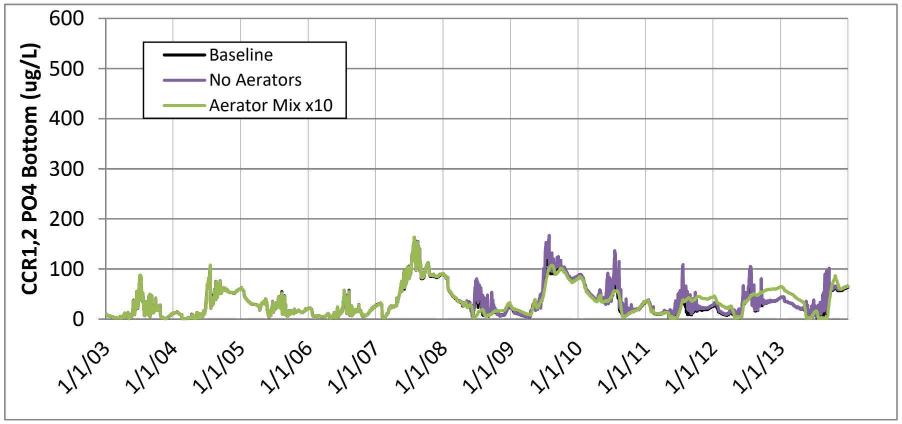

CCR1,2 Ammonia (0-3 m; ug/L)
Baseline
Aerator Mix x10
No Aerators
400
350
300
250
200
150
100
50
0
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13

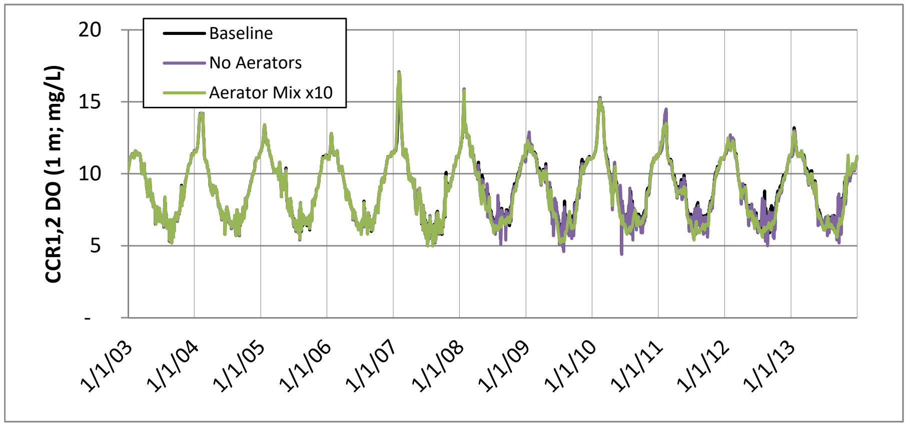

CCR1,2 Ammonia Bottom (ug/L)
Baseline
No Aerators
Aerator Mix x10
400
350
300
250
200
150
100
50
-
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13

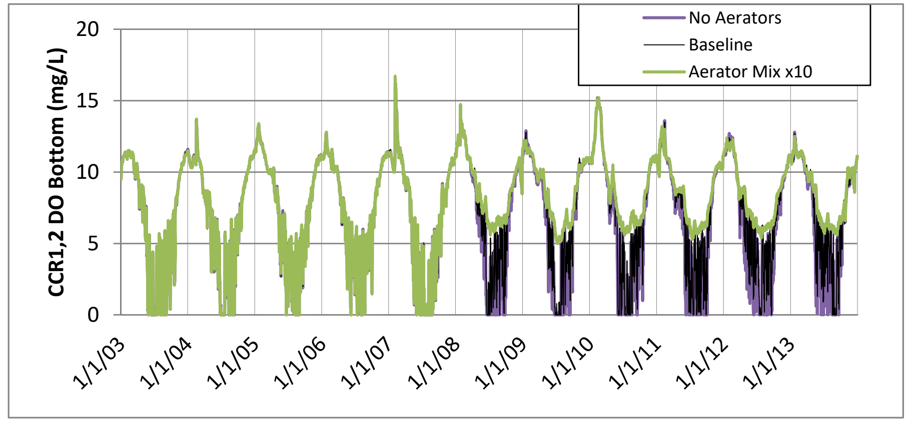

CCR1,2 NOx (0-3 m; ug/L)
Baseline
No Aerators
Aerator Mix x10
1,000
800
600
400
200
-
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13

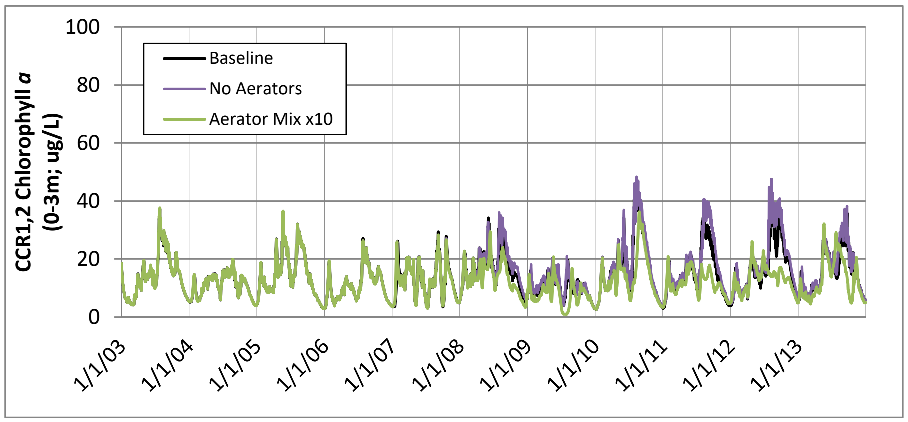

CCR1,2 NOx Bottom (ug/L)
Baseline
No Aerators
Aerator Mix x10
1,000
800
600
400
200
-
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13

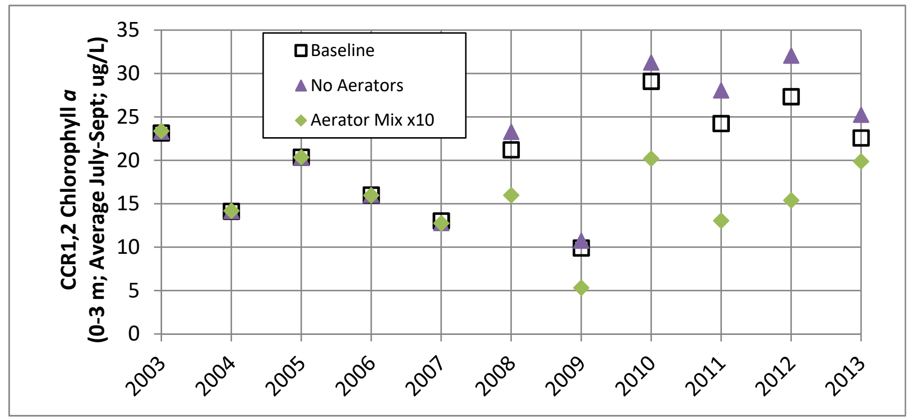

CCR1,2 PO4 (0-3 m; ug/L)
Baseline
No Aerators
Aerator Mix x10
600
500
400
300
200
100
-
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13

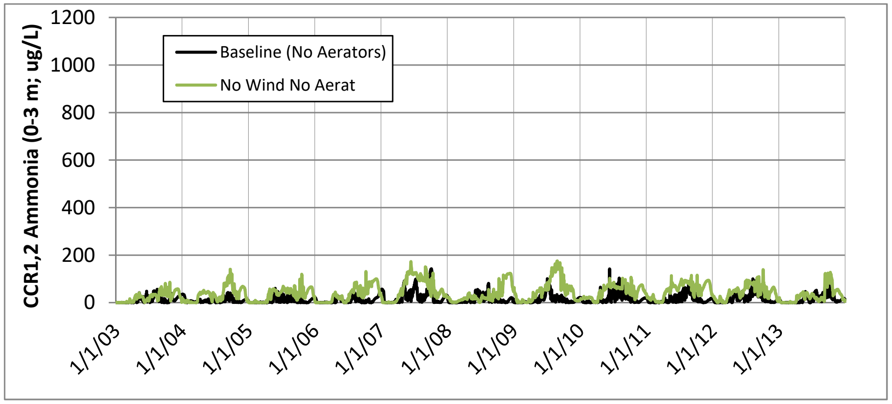

CCR1,2 PO4 Bottom (ug/L)
Baseline
No Aerators
Aerator Mix x10
600
500
400
300
200
100
0
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13

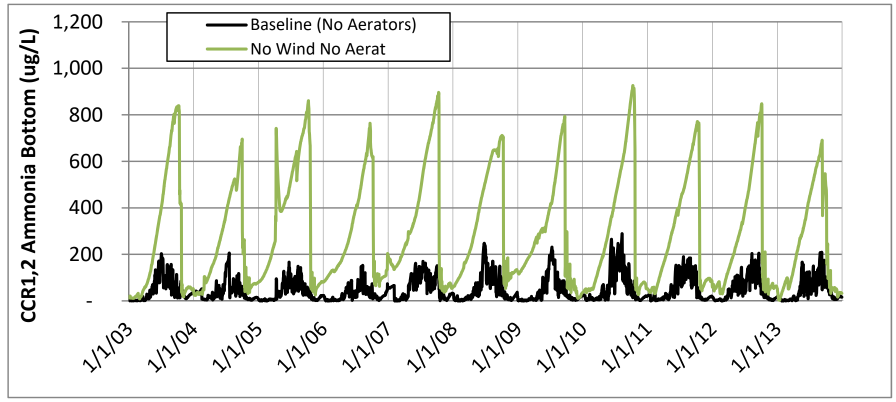

Baseline
No Aerators
Aerator Mix x10
CCR1,2 DO (1 m; mg/L)
20
15
10
5
-
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13

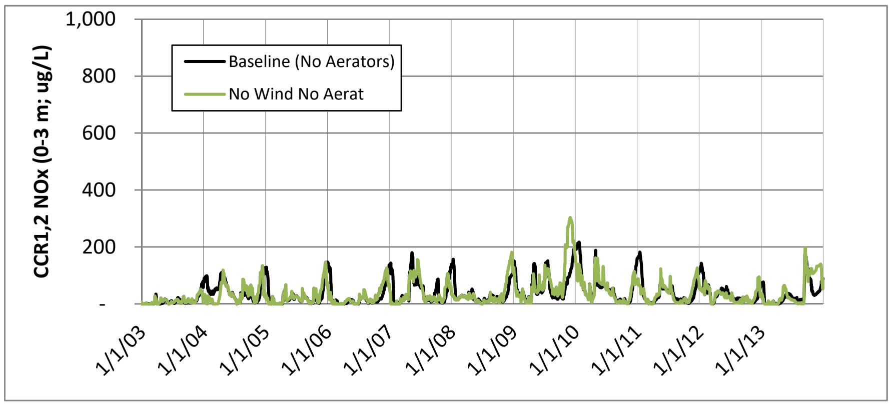

No Aerators
Baseline
Aerator Mix x10
CCR1,2 DO Bottom (mg/L)
20
15
10
5
0
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13

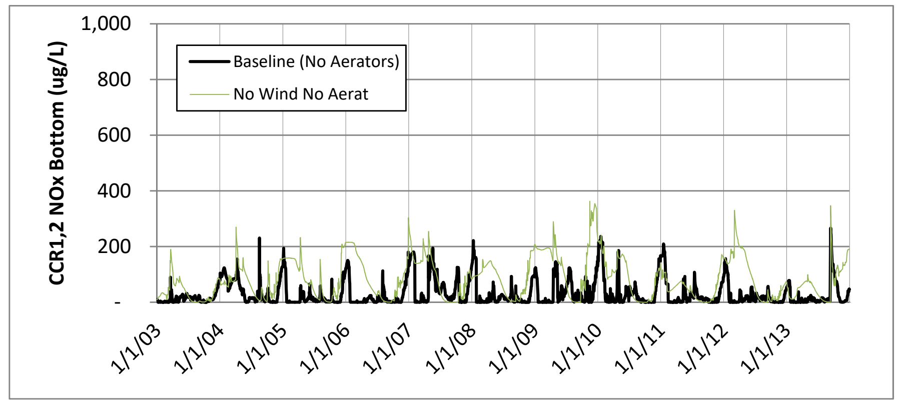

Baseline
No Aerators
Aerator Mix x10
CCR1,2 Chlorophyll a
(0-3m; ug/L)
100
80
60
40
20
0
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13

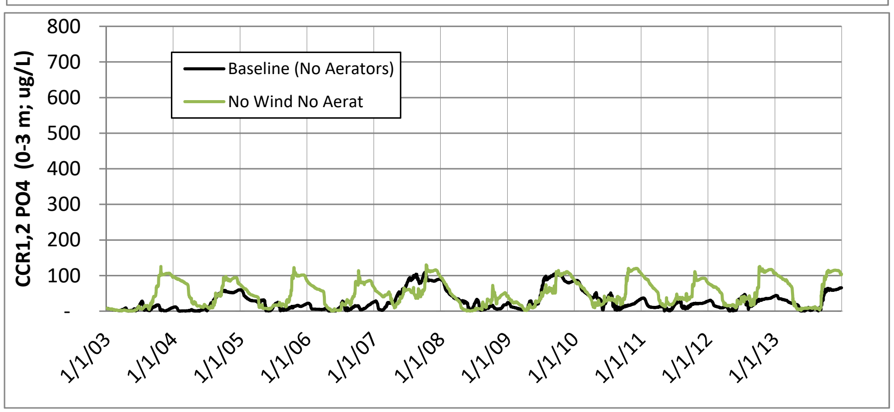

Baseline
No Aerators
Aerator Mix x10
CCR1,2 Chlorophyll a
(0-3 m; Average July-Sept; ug/L)
35
30
25
20
15
10
5
0
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013

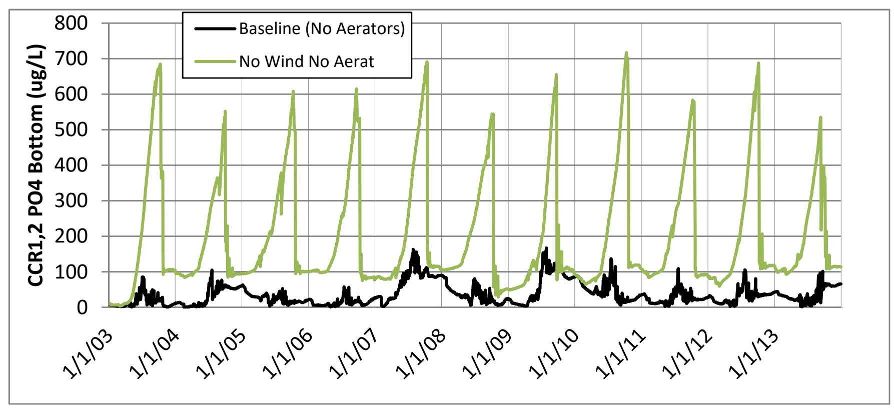

CCR1,2 Ammonia (0-3 m; ug/L)
Baseline (No Aerators)
No Wind No Aerat

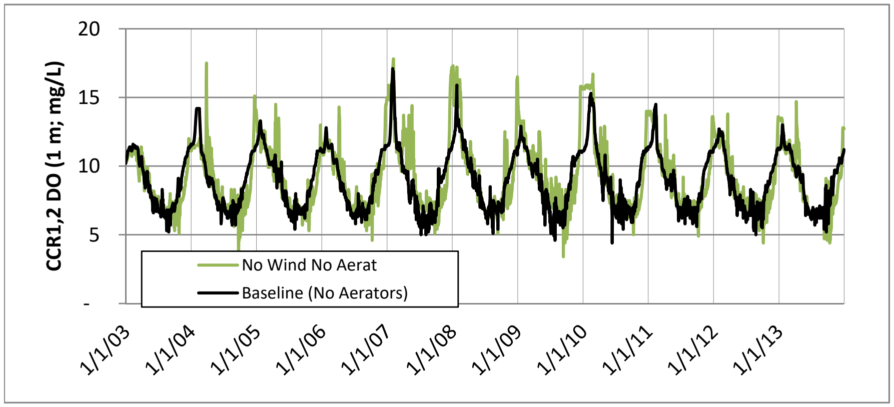

CCR1,2 Ammonia Bottom (ug/L)
Baseline (No Aerators)
No Wind No Aerat

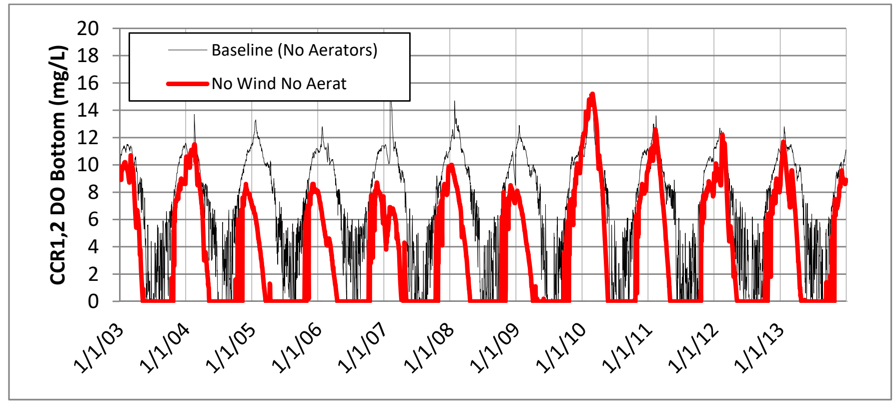

CCR1,2 NOx (0-3 m; ug/L)
Baseline (No Aerators)
No Wind No Aerat

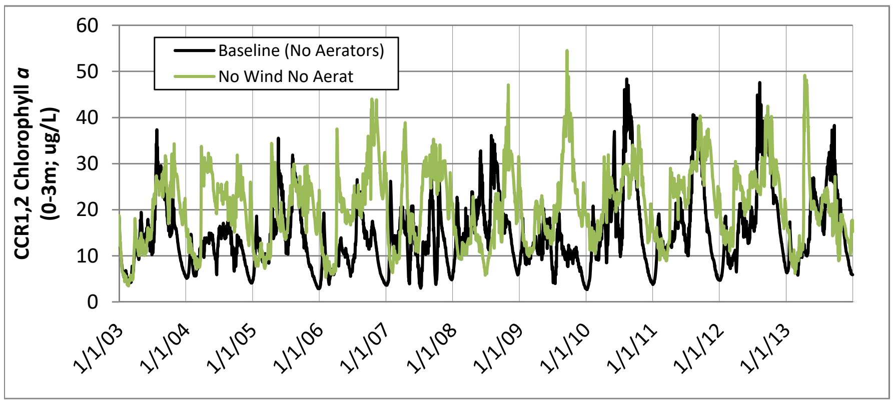

CCR1,2 NOx Bottom (ug/L)
Baseline (No Aerators)
No Wind No Aerat

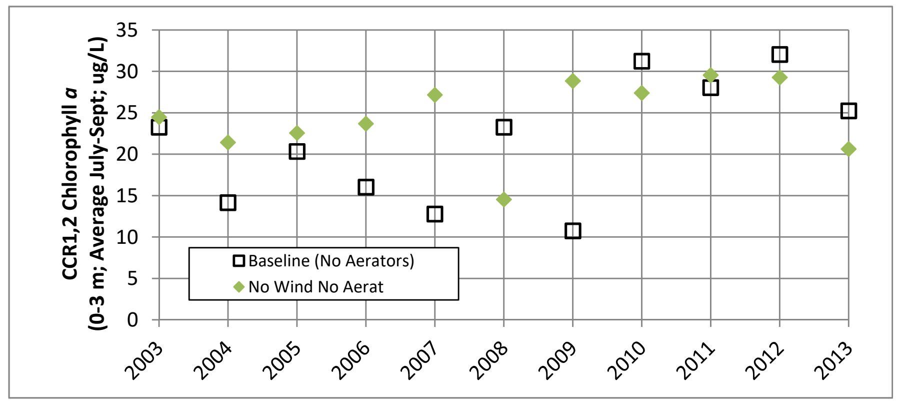

CCR1,2 PO4 (0-3 m; ug/L)
Baseline (No Aerators)
No Wind No Aerat

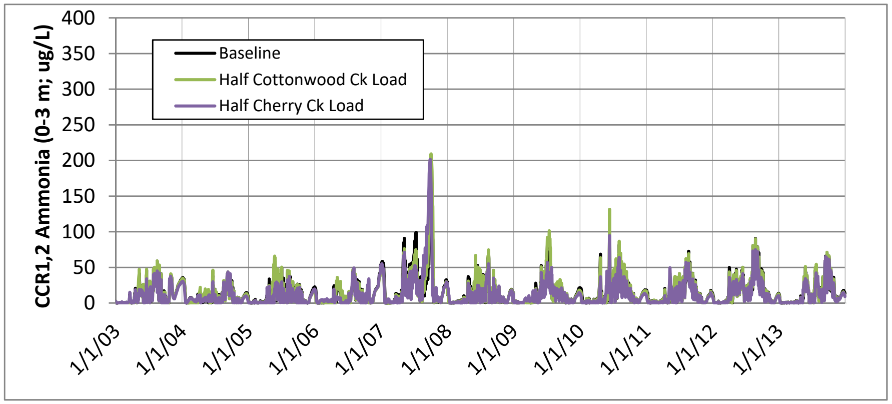

CCR1,2 PO4 Bottom (ug/L)
Baseline (No Aerators)
No Wind No Aerat

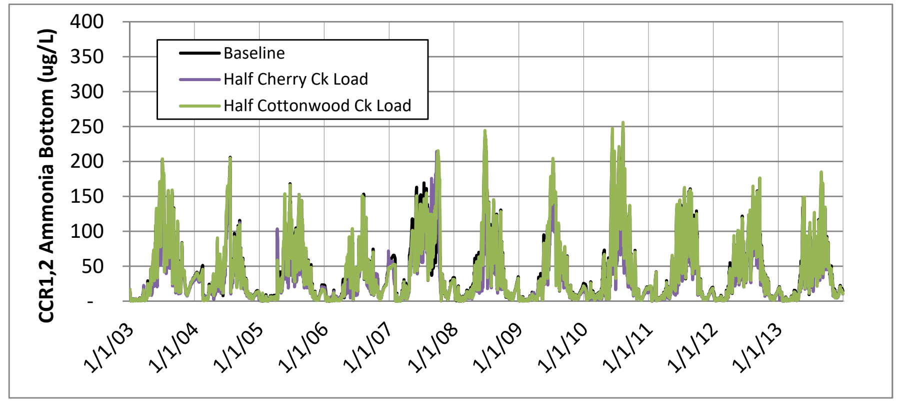

CCR1,2 DO (1 m; mg/L)
No Wind No Aerat
Baseline (No Aerators)
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13

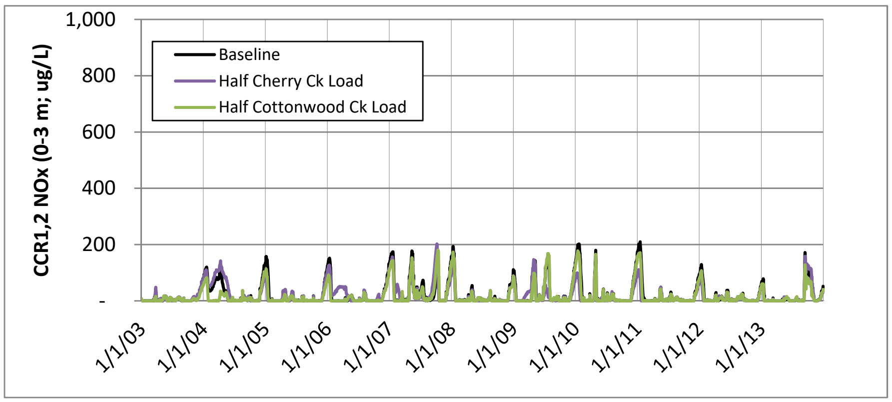

CCR1,2 DO Bottom (mg/L)
Baseline (No Aerators)
No Wind No Aerat
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13

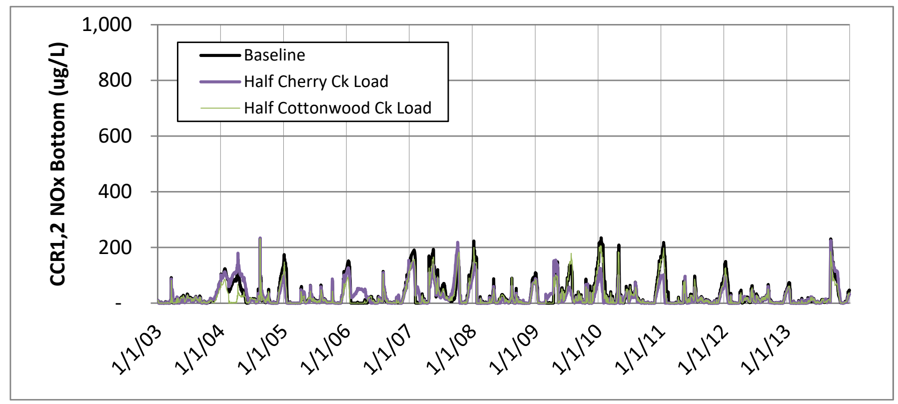

CCR1,2 Chlorophyll a
(0-3m; ug/L)
Baseline (No Aerators)
No Wind No Aerat
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13

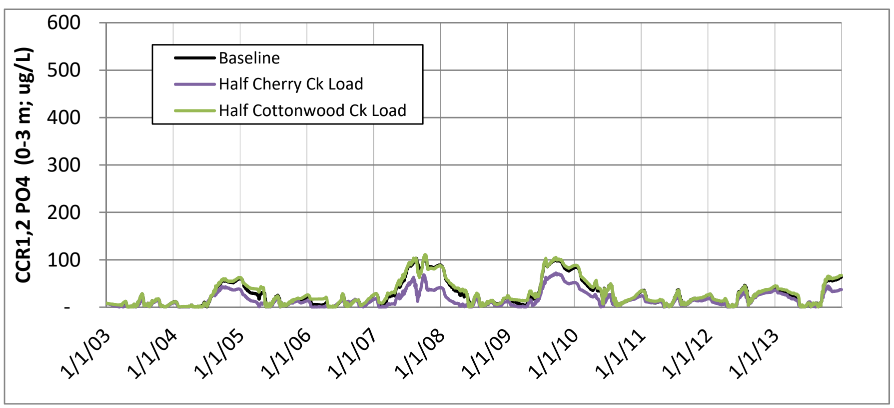

CCR1,2 Chlorophyll a
(0-3 m; Average July-Sept; ug/L)
Baseline (No Aerators)
No Wind No Aerat
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013

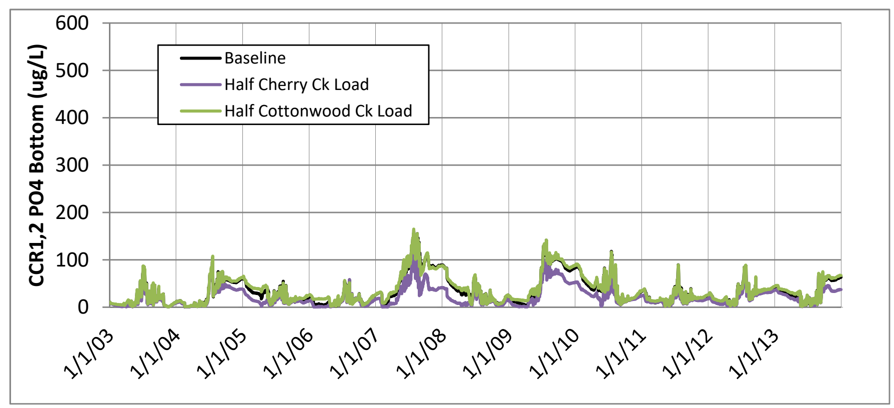

CCR1,2 Ammonia (0-3 m; ug/L)
Baseline
Half Cottonwood Ck Load
Half Cherry Ck Load

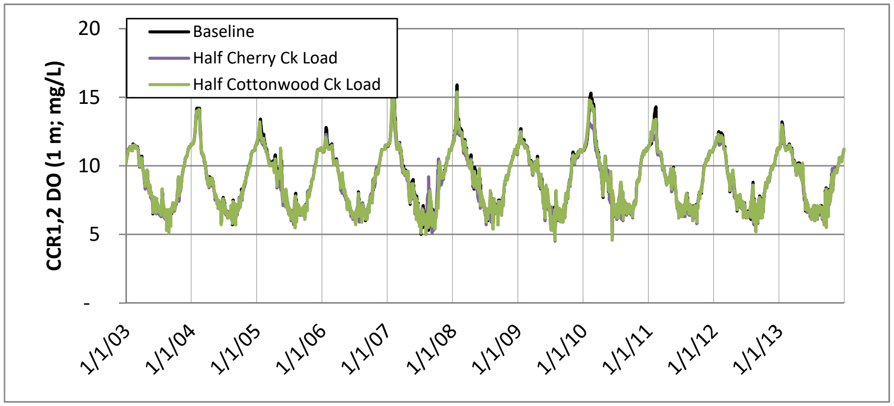

CCR1,2 Ammonia Bottom (ug/L)
Baseline
Half Cherry Ck Load
Half Cottonwood Ck Load

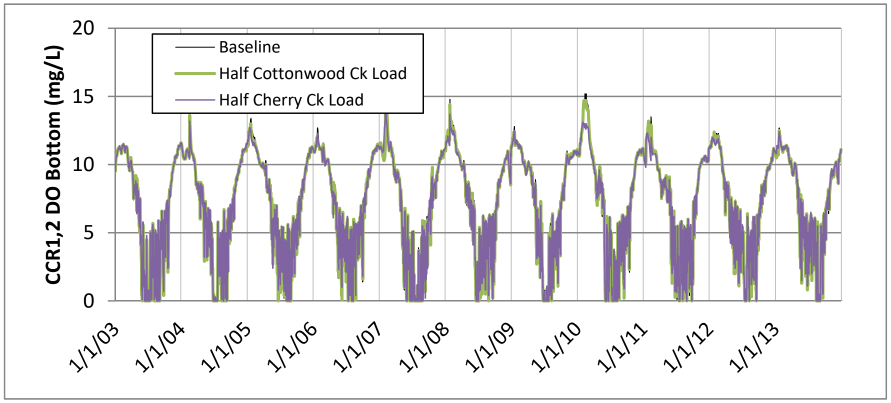

CCR1,2 NOx (0-3 m; ug/L)
Baseline
Half Cherry Ck Load
Half Cottonwood Ck Load

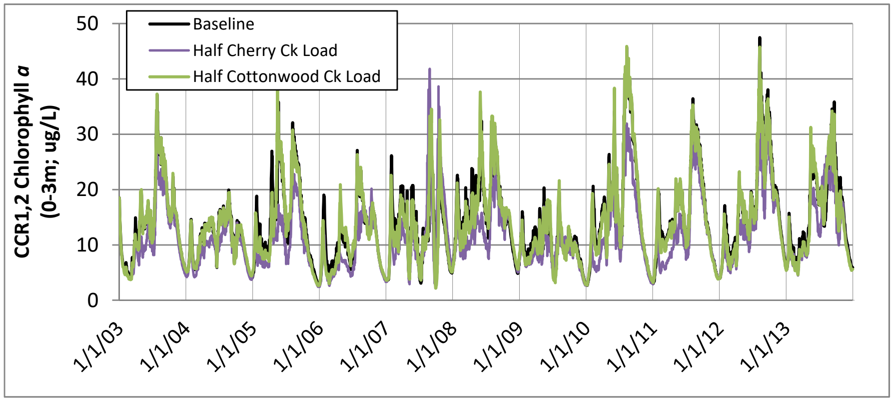

CCR1,2 NOx Bottom (ug/L)
Baseline
Half Cherry Ck Load
Half Cottonwood Ck Load

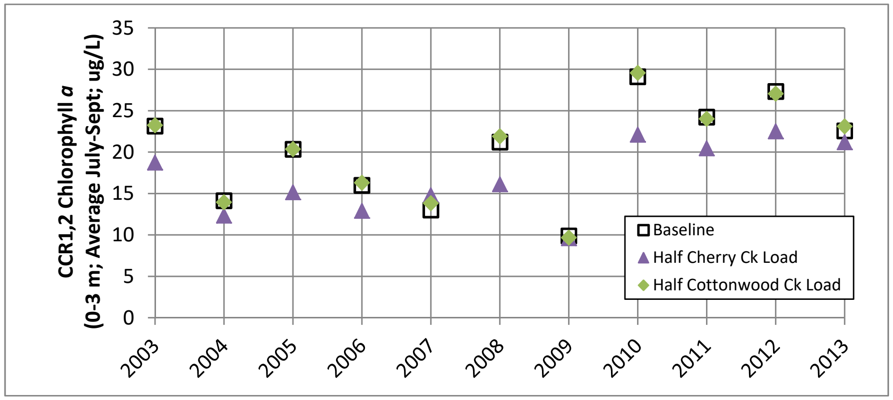

CCR1,2 PO4 (0-3 m; ug/L)
Baseline
Half Cherry Ck Load
Half Cottonwood Ck Load

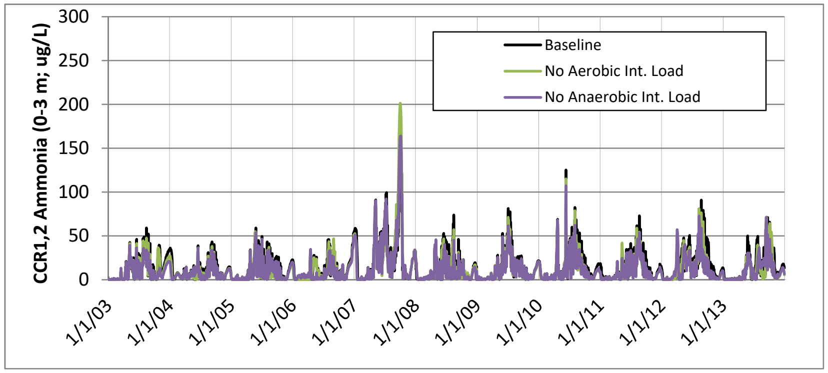

CCR1,2 PO4 Bottom (ug/L)
Baseline
Half Cherry Ck Load
Half Cottonwood Ck Load

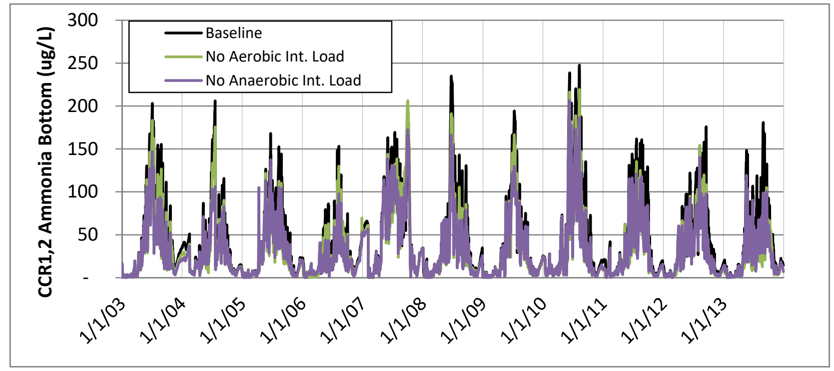

CCR1,2 DO (1 m; mg/L)
20
15
10
5
-
Baseline
Half Cherry Ck Load
Half Cottonwood Ck Load
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13

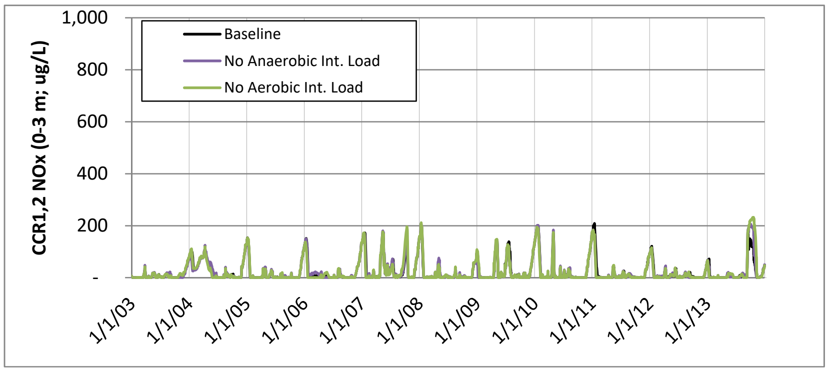

CCR1,2 DO Bottom (mg/L)
20
15
10
5
0
Baseline
Half Cottonwood Ck Load
Half Cherry Ck Load
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13

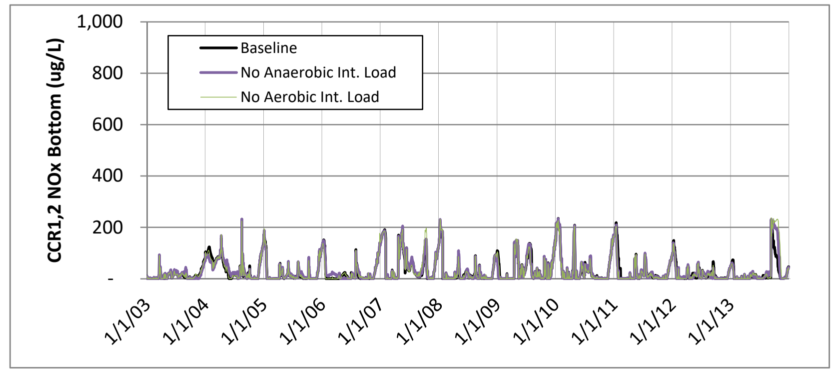

CCR1,2 Chlorophyll a (0-3m; ug/L)
50
40
30
20
10
0
Baseline
Half Cherry Ck Load
Half Cottonwood Ck Load
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13

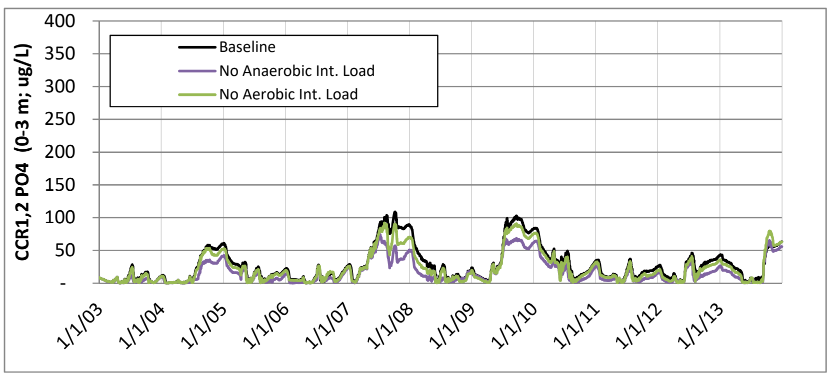

CCR1,2 Chlorophyll a (0-3 m; Average July-Sept; ug/L)
35
30
25
20
15
10
5
0
Baseline
Half Cherry Ck Load
Half Cottonwood Ck Load
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013

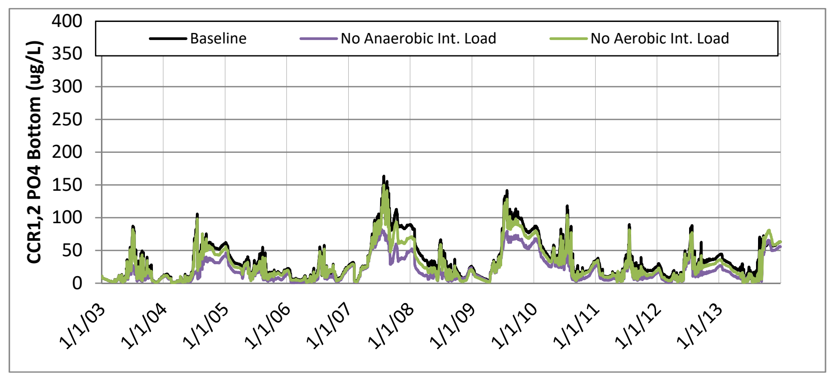

CCR1,2 Ammonia (0-3 m; ug/L)
300
250
200
150
100
50
0
Baseline
No Aerobic Int. Load
No Anaerobic Int. Load
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13

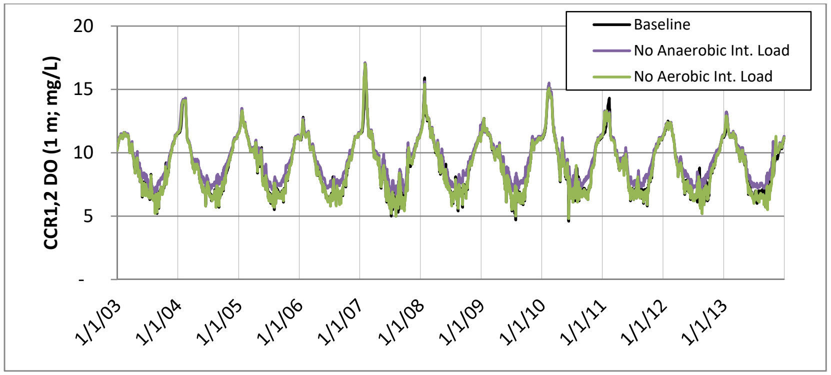

CCR1,2 Ammonia Bottom (ug/L)
300
250
200
150
100
50
-
Baseline
No Aerobic Int. Load
No Anaerobic Int. Load
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13

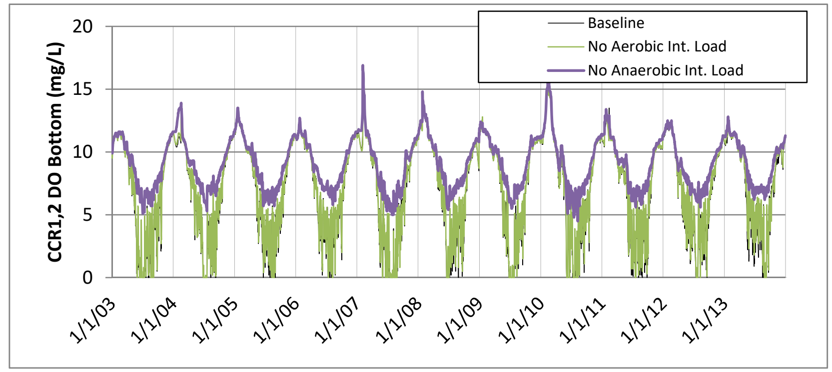

CCR1,2 NOx (0-3 m; ug/L)
1,000
800
600
400
200
-
Baseline
No Anaerobic Int. Load
No Aerobic Int. Load
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13

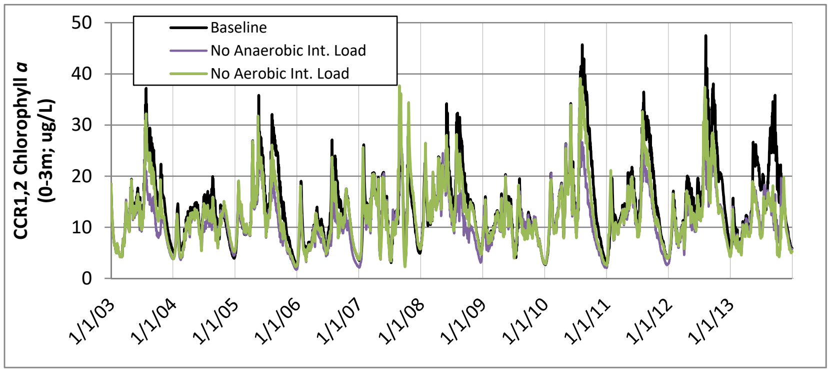

CCR1,2 NOx Bottom (ug/L)
1,000
800
600
400
200
-
Baseline
No Anaerobic Int. Load
No Aerobic Int. Load
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13


CCR1,2 PO4 (0-3 m; ug/L)
400
350
300
250
200
150
100
50
-
Baseline
No Anaerobic Int. Load
No Aerobic Int. Load
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13


CCR1,2 PO4 Bottom (ug/L)
400
350
300
250
200
150
100
50
0
Baseline
No Anaerobic Int. Load
No Aerobic Int. Load
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13


CCR1,2 DO (1 m; mg/L)
Baseline
No Anaerobic Int. Load
No Aerobic Int. Load
20
15
10
5
-
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13


CCR1,2 DO Bottom (mg/L)
Baseline
No Aerobic Int. Load
No Anaerobic Int. Load
20
15
10
5
0
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13


CCR1,2 Chlorophyll a
(0-3m; ug/L)
Baseline
No Anaerobic Int. Load
No Aerobic Int. Load
50
40
30
20
10
0
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
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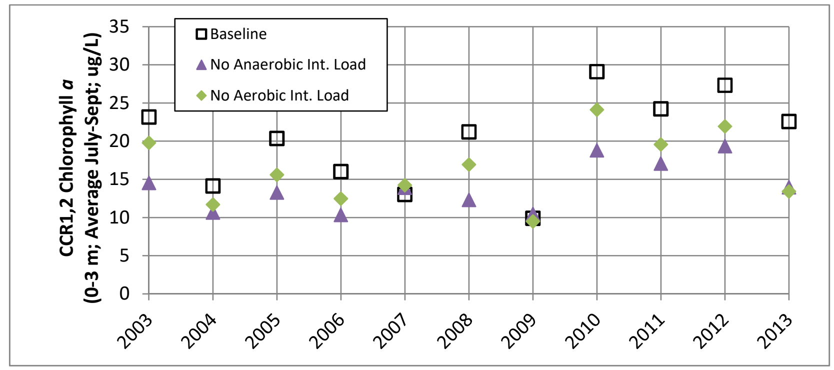
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13


CCR1,2 Chlorophyll a
(0-3 m; Average July-Sept; ug/L)
Baseline
No Anaerobic Int. Load
No Aerobic Int. Load
35
30
25
20
15
10
5
0
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013

Attachment E: Simplifying Assumptions in CE-QUAL-W2 Noted in Main Report Section 4.3

Attachment E: Simplifying Assumptions Noted in Main Report Section 5.3

The reservoir exhibits significant cycling of nutrients between the water column and the sediments. Aerobic and anaerobic decay of organic matter in the sediments releases ammonia and PO4. Algae take up nutrients and eventually settle to the sediment surface decaying in the water column while settling or at the sediment-water-interface. Due to sporadic mixing from the bottom to the top in summer months, these products of algal decay are reintroduced to the surface of Cherry Creek Reservoir at times throughout the growing season. Such rapidly-changing dynamics can be a challenge to capture in numerical modeling; however, the calibrated Cherry Creek model is simulating these major nutrient cycling mechanisms. As with any generic purpose modeling software, there are simplifying assumptions in CE-QUAL-W2 v.3.72. Some of these simplifying assumptions may explain some remaining variation in simulated and observed nutrient responses. These are not suggested as critical model refinement needs; the calibrated model is a powerful and useful tool for the Authority as is. Instead these are described here to support an informed review of results:

- **Constant Sediment Burial Rates:** The sediment burial rate in the model is a constant value. This setting defines a loss rate of settled detritus (primarily algae in this system) from the sediment compartment that would be available of aerobic decay. It is likely that this burial rate varies over time, responding to effects such as storm loading of higher concentrations of solids. Sediment diagenesis simulation may (or may not) be beneficial in improving time-varying response related to sediment burial rates. W2 v.4.0 version, including sediment diagenesis has become available since the start of this project. However, based on the schedule and budget, use of this updated tool has been deferred for future refinements. No modifications are recommended as critical at this time.
- **Fixed Stoichiometry of Algae:** The stoichiometry of algae is a constant in the model, but in reality can vary over time. Excess PO4, in particular, can be taken up and stored by algae when it is available in abundance. This is termed “luxury uptake”. The model does not currently simulate luxury uptake; however, recoding this effect may be helpful for future Cherry Creek modeling refinements. Given high concentrations of excess PO4 (relative to nitrate and ammonia) present at the top of the reservoir, simulation of luxury uptake could improve the simulation of PO4 response in Cherry Creek. No modifications are recommended as critical at this time.
- **Simplistic Sorption of Phosphorus to Particulate Material:** The model allows for sorption and subsequent settling of phosphate to inorganic suspended solids and iron oxides; however, the sorbed fraction is a constant that is proportional to the mass of the solids in the system. As such it does not take into account surface area or surface chemistry of suspended solids. As a result the model simulates rapid, early season loss of phosphate through settling with the heavy fraction of larger suspended solids entering the system with runoff. Because of this, the built-in sorption options in W2 were not applied. The model preforms well in the absence of additional refinements to this mechanisms, however, future refinements in this area could possibly improve the phosphate simulation. No modifications are recommended as critical at this time.

Attachment F: Assumed Inflow Concentrations for Management Runs 1, 3, and 5 Compared to Observed Concentrations

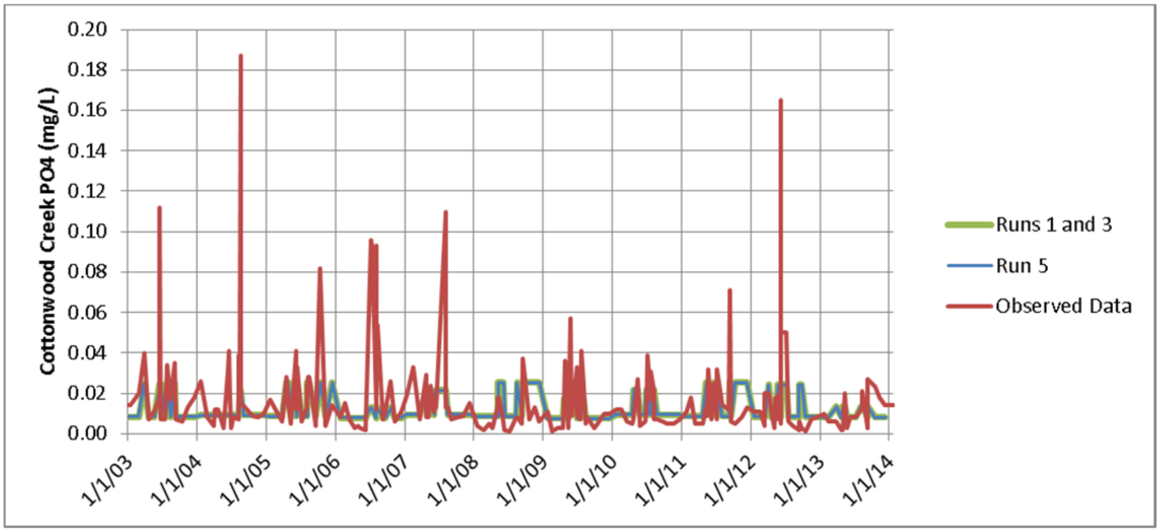


Figure 1. Input Orthophosphate from Cottonwood Creek into Cherry Creek Reservoir: Observed Data and Assumed Concentrations for Management Runs 1, 3, and 5 (Run Assumptions Provided by Leonard Rice Engineers, Inc.).

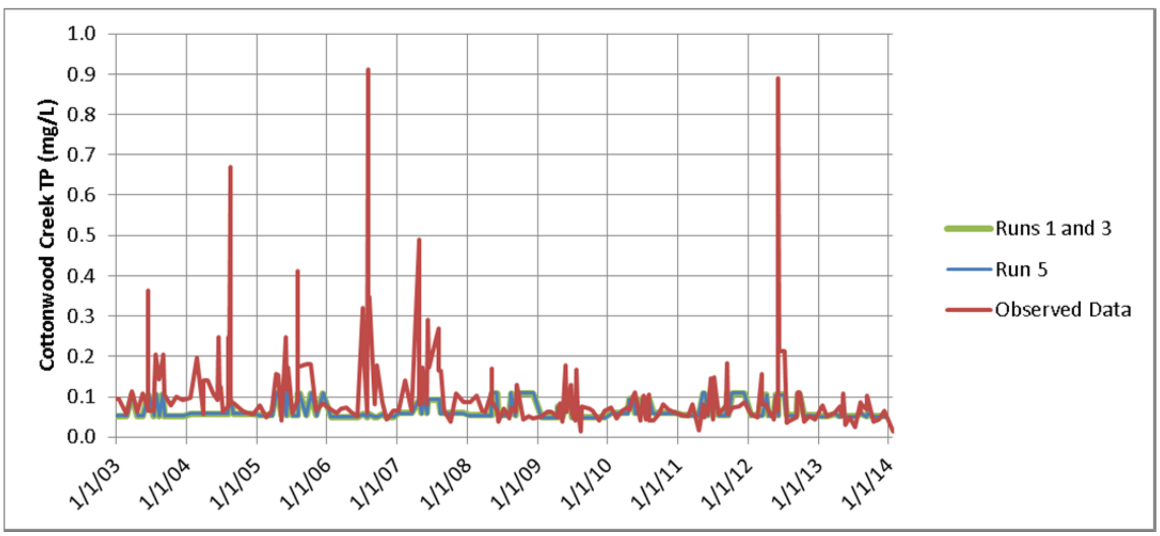


Figure 2. Simulated Total Phosphorus from Cottonwood Creek into Cherry Creek Reservoir: Observed Data and Assumed Concentrations for Management Runs 1, 3, and 5 (Run Assumptions Provided by Leonard Rice Engineers, Inc.).

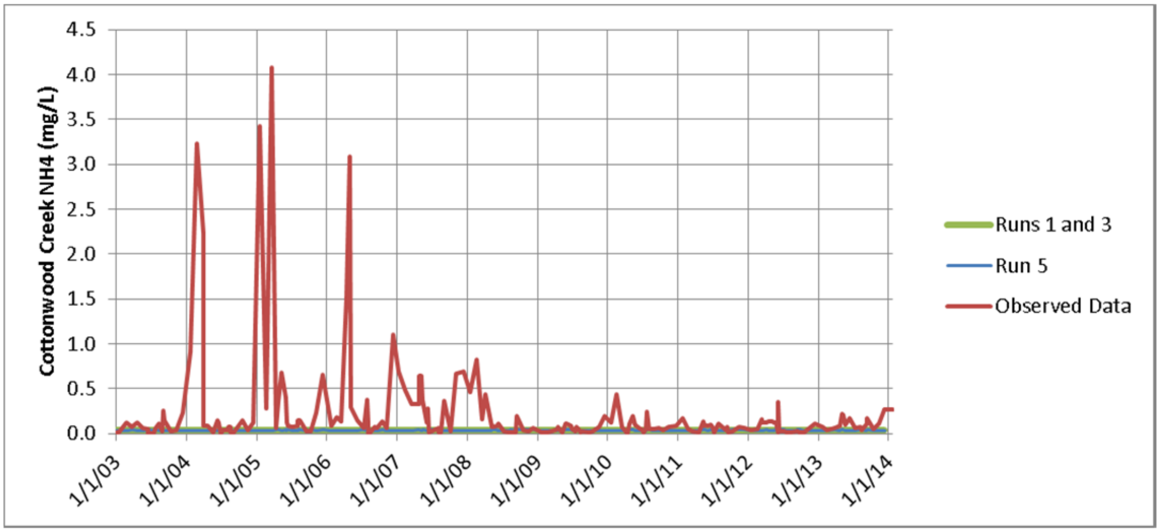


Figure 3. Input Ammonia from Cottonwood Creek into Cherry Creek Reservoir: Observed Data and Assumed Concentrations for Management Runs 1, 3, and 5 (Run Assumptions Provided by Leonard Rice Engineers, Inc.).

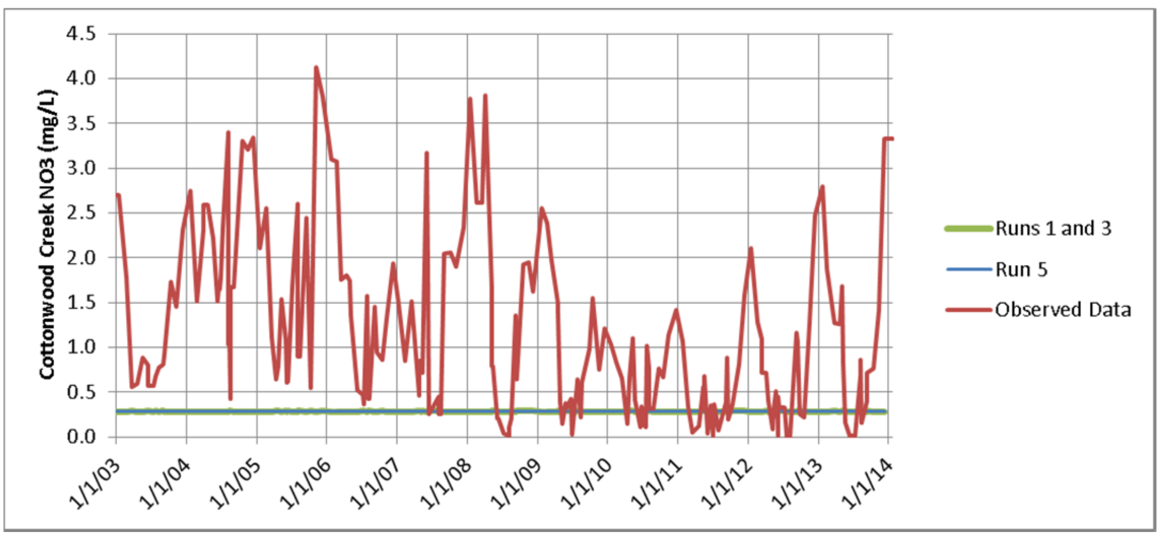


Figure 4. Simulated Nitrate from Cottonwood Creek into Cherry Creek Reservoir: Observed Data and Assumed Concentrations for Management Runs 1, 3, and 5 (Run Assumptions Provided by Leonard Rice Engineers, Inc.).

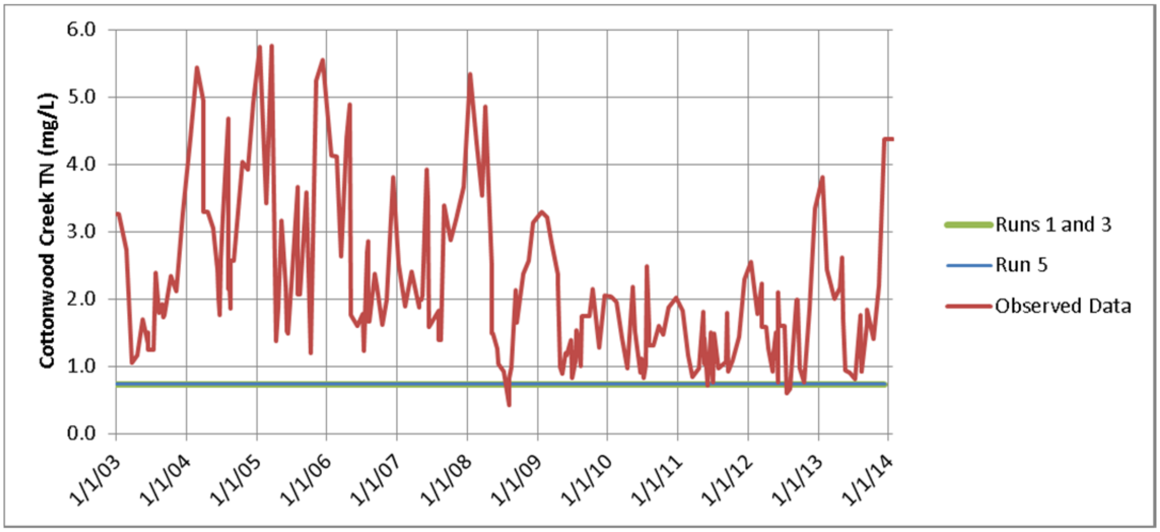


Figure 5. Input Total Nitrogen from Cottonwood Creek into Cherry Creek Reservoir: Observed Data and Assumed Concentrations for Management Runs 1, 3, and 5 (Run Assumptions Provided by Leonard Rice Engineers, Inc.).

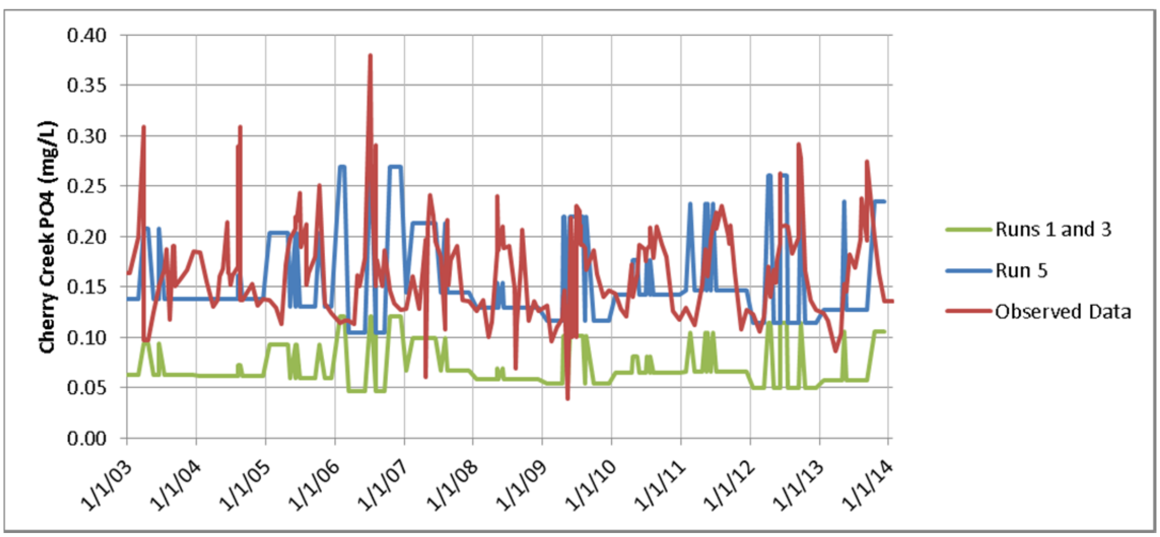


Figure 6. Simulated Orthophosphate from Cherry Creek into Cherry Creek Reservoir: Observed Data and Assumed Concentrations for Management Runs 1, 3, and 5 (Run Assumptions Provided by Leonard Rice Engineers, Inc.).

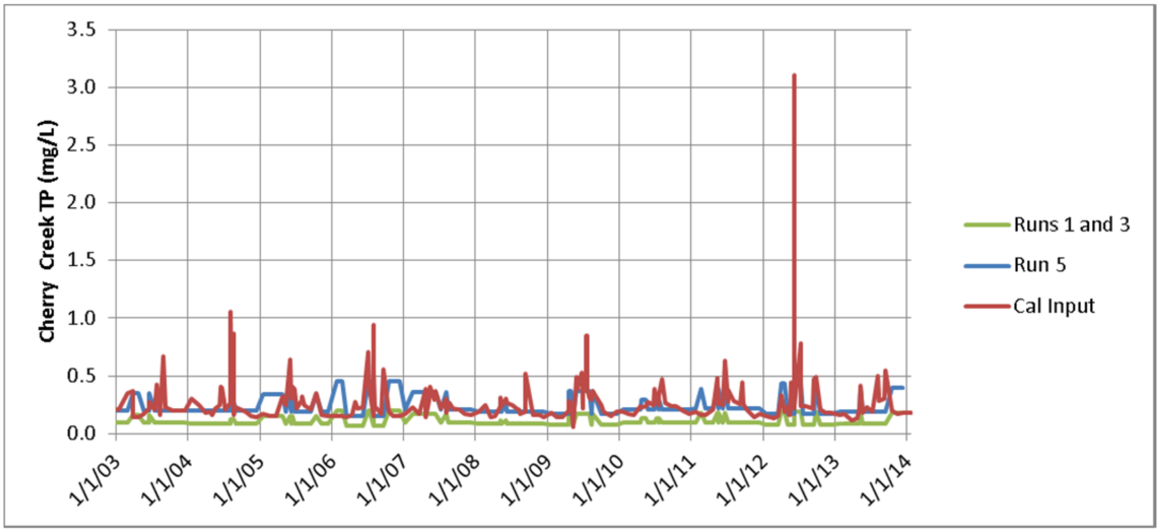


Figure 7. Input Total Phosphorus from Cherry Creek into Cherry Creek Reservoir: Observed Data and Assumed Concentrations for Management Runs 1, 3, and 5 (Run Assumptions Provided by Leonard Rice Engineers, Inc.).

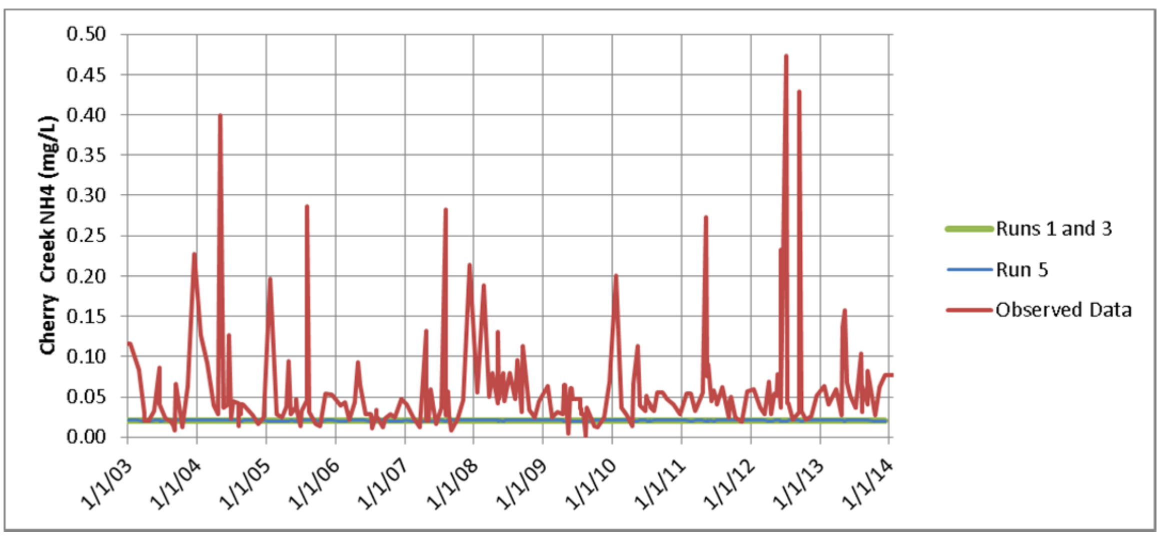


Figure 8. Simulated Ammonia from Cherry Creek into Cherry Creek Reservoir: Observed Data and Assumed Concentrations for Management Runs 1, 3, and 5 (Run Assumptions Provided by Leonard Rice Engineers, Inc.).

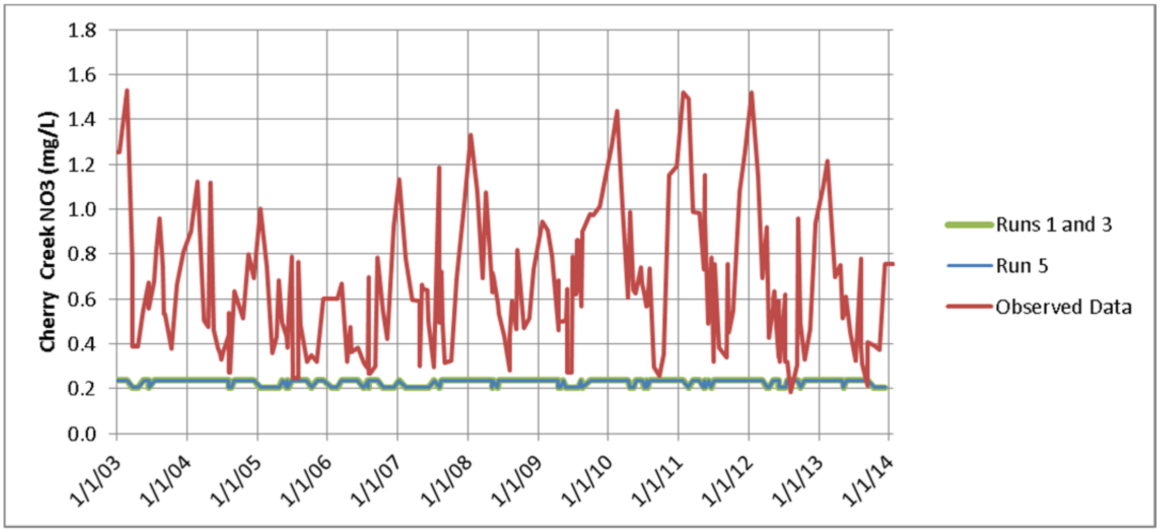


Figure 9. Input Nitrate from Cherry Creek into Cherry Creek Reservoir: Observed Data and Assumed Concentrations for Management Runs 1, 3, and 5 (Run Assumptions Provided by Leonard Rice Engineers, Inc.).

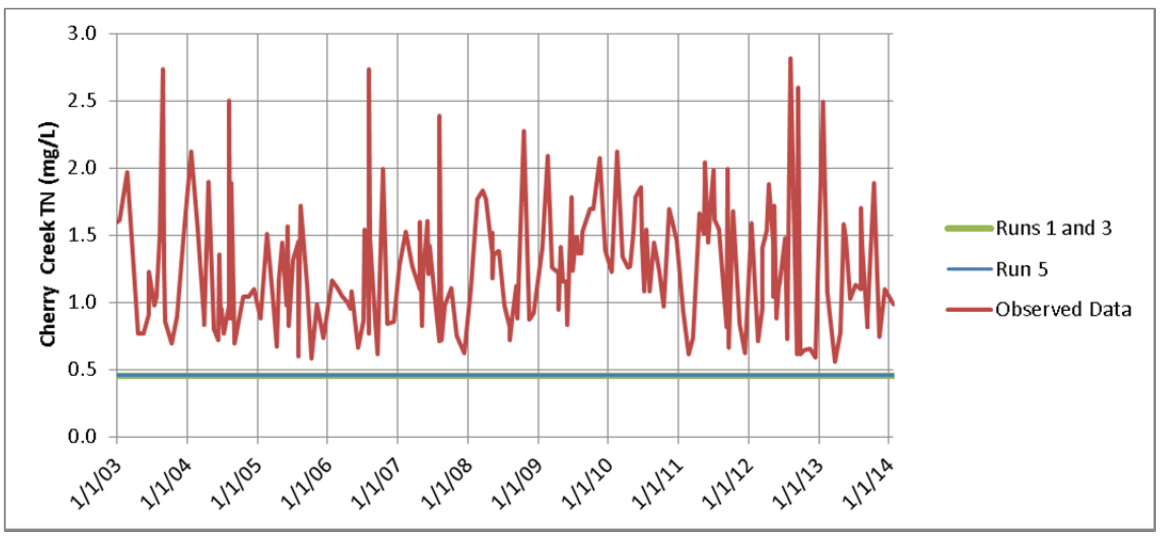


Figure 10. Input Total Nitrogen from Cherry Creek into Cherry Creek Reservoir: Observed Data and Assumed Concentrations for Management Runs 1, 3, and 5 (Run Assumptions Provided by Leonard Rice Engineers, Inc.).

Attachment G: Response to Comments from Dr. S. Wells on Draft Calibration

Contents:

Masseh College of Engineering and Computer Science
Department of Civil and Environmental Engineering

Post Office Box 751 503-725-4282 tel
Portland, Oregon 97207-0751 503-725-5950 fax
wellss@pdx.edu

June 22, 2015

To: Jean Marie Boyer, Christine Hawley, Hydros Consulting Inc.

From: Scott A. Wells

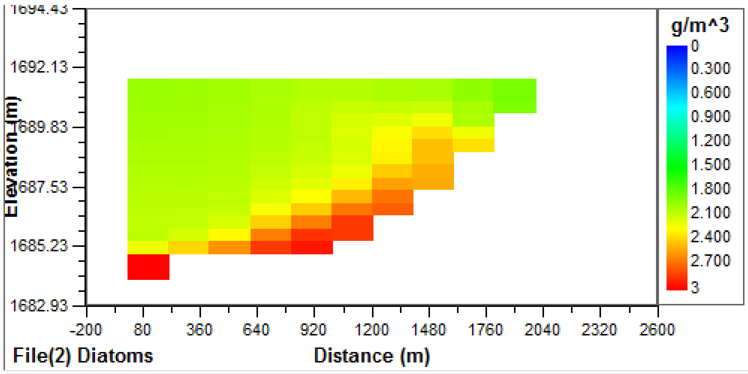
C: Craig Wolfe, GEI

Re: Peer review of Cherry Creek Reservoir model calibration

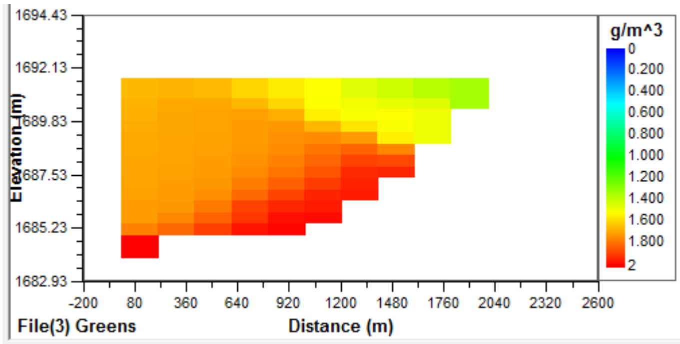
This memorandum summarizes the results of a meeting on June 22, 2015 in Boulder, Co, at the Hydros' office where the Cherry Creek Reservoir calibration was reviewed. Below are a list of possible areas to evaluate for model improvement. These areas may or may not affect the current state of the model calibration but may make the final model result more defensible, help in understanding the strengths and weaknesses of the model, and help us point to gaps in our understanding of the reservoir that additional field sampling can help reduce.

1. The current model uses the W2N turbulence closure scheme with a maximum value of Az set to 0.0001 m^2/s. The recommended turbulence closure scheme is a more general formulation, the k-e turbulence model, specified as TKE, with a maximum value set to 1.0 m^2/s. Hence, one does not over-constrain possible vertical mixing with the lower limit to Az.
2. Comparing field data of light extinction to model prediction of light extinction would be an important check on predicting light transmission as it affects algae growth.
3. With the large amount of particulate organic and inorganic matter in the reservoir, a comparison of TSS and VSS (which would be LPOM, RPOM, and total algae in the model) could affect the model's ability to predict dynamically the light extinction coefficient. This is especially true since the average inflow of ISS from Cherry Creek is over 40 mg/l with a peak of 1600 mg/l.
4. The low values of ASAT for the first 2 algae groups of 20 W/m^2 seem low. There are cases where algae growth is concentrated at the bottom of the model perhaps by settling and the low value of ASAT.

Note the 'diatom' group model predicted growth in May of the first year with the unusual growth at the bottom of the reservoir (this is common in most years).



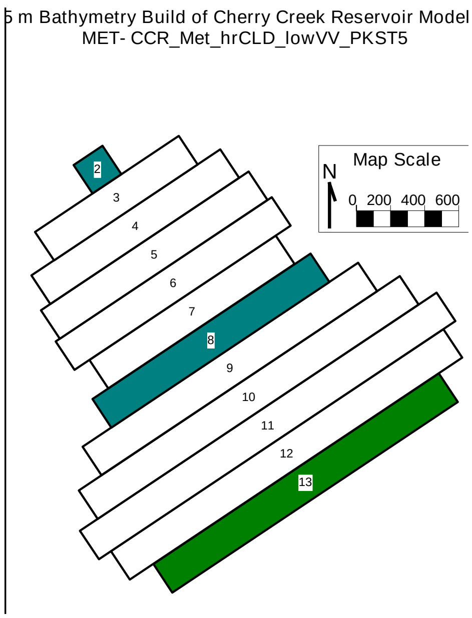
In April of the first year (Day 101.2) for the group called 'greens' also showed similar behavior:



This growth at the bottom may be due to too much light penetration and low values of ASAT or due to inflow density currents. I would encourage animating the various water quality parameters to make sure behavior is as intended.

5. pH was not modeled in this simulation but it can be a useful state variable since it helps verify aerobic sediment processes by closing the loop on a C balance. This may require looking at the boundary conditions for TIC and alkalinity that are currently constant over time.
6. The model computes TDS as a state variable. It was mentioned an increase in TDS has occurred over the last few years as a result of increased TDS from the tributaries. Were there comparisons to field data?
7. Aeration input (mass of O2 delivered by the aerators) was calibrated to match dissolved oxygen profiles. A check should be made on the actual amount of oxygen delivered by the aeration system and whether the calibrated amount added seems reasonable.
8. During the fish kill in 2012 (?), C, N, and P were added to the aerobic sediments during this period. The amounts added should be checked to see if they are reasonable based on observations.
9. Zooplankton data collected in later years of the model calibration should be compared to field data for zooplankton during these years if zooplankton are used in the model. Even though there have been hypotheses for zooplankton productivity throughout the period of model calibration, the model should have zooplankton during the entire period of the model. It may be that some of the mortality functions of zooplankton (or for that matter algae) may be time dependent but are represented in the model as static values.

10. In addition to the extensive model-data comparisons presented (profiles and time series graphs), animations, contour plots and velocity vectors plots may be helpful to visualize the model predicted behavior of the reservoir.
11. The zero order and first order models are used for sediment impacts. Since the zero order SOD model is not predictive but varies only by temperature, one may want to experiment (if there are time/resources available) with the Version 4 model with the fully predictive SOD model. This will require turning off the zero and first order models.
12. Some documentation should be provided for the high ratio of refractory to labile organic matter coming into the model since it is currently set at 10% labile and 90% refractory.
13. The model grid bathymetry orientation angles are off by 180 degrees. This may affect how the lake responds to the wind.



14. Since biovolume species data exist, it would be useful to compare for different seasons model predicted species composiiton even though the groups may not be exactly aligned with the biovolume species data.
15. Since field data are collected at the outlet to Cherry Creek Reservoir, model predictions of outlet water quality and temperature could be compared to these field data. This provides a check on selective withdrawal of the model and the reservoir's water quality.
16. For performing sensitivity runs with the model, looking at the sensitivity of the model to wind or meterological conditiosn (by varying WSC or using a different meteorologcial file such as from another site) and zero order SOD would be useful.
17. The low dissolved oxygen in the surface of the model during the early years seems to be related to too high SOD during these periods since the largest source/sink is SOD. Changing the reaeration coefficient and/or O2AG may not affect the under-prediction of dissolved oxygen since SOD dominated the oxygen balance (from what I recall seeing in the presentation).

18. Since you have made code changes, make sure you are using the exact settings for the Intel Visual Fortran compiler used to compile the release executable. Issues with precision of real numbers can greatly affect the model results.
19. It would also be helpful to report mean error in the error statistics in additon to your absolute mean error and RMS since this indicates bias.

In general, the calibration is well advanced and the work performed to date has been reasonable and has been moving in the right direction. Even though some of these items above may adjust the model calibration, it should not take too much of an effort to return to what had already seemed a reasonable calibration that is more defensible in understanding processes in the reservoir.

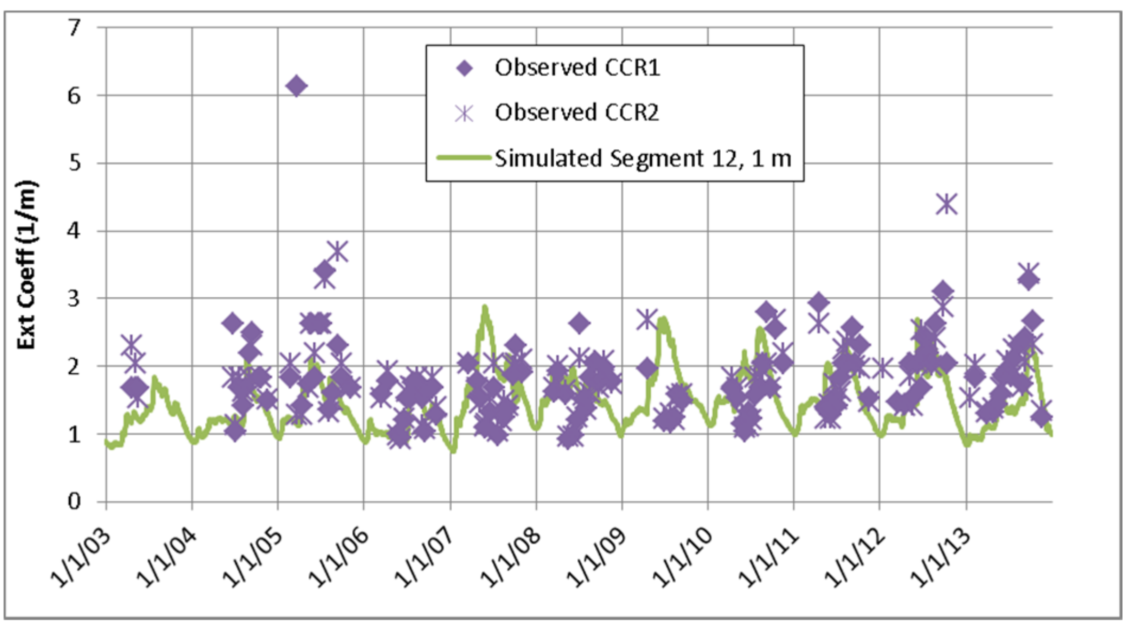
Hydros is grateful to Dr. Wells for his thoughtful and insightful comments in review of the draft calibrated model. All comments were carefully considered. The process of resolving issues brought up in these comments led to important model improvements, resulting in a more defensible product. The following is a comment-by-comment response to items in the memorandum from Dr. Wells. Comments were created for the first calibrated version of the model (July 31, 2015). Comments have been updated to reflect additional changes made during recalibration of the model (completed 9/9/16).

1. The current model uses the W2N turbulence closure scheme with a maximum value of Az set to 0.0001 m_2/s. The recommended turbulence closure scheme is a more general formulation, the k-e turbulence model, specified as TKE, with a maximum value set to 1.0 m_2/s. Hence, one does not over-constrain possible vertical mixing with the lower limit to Az.

The turbulence closure scheme has been changed to TKE with a maximum value set to 1.0 m^2/s. The change to the simulation response was minimal.

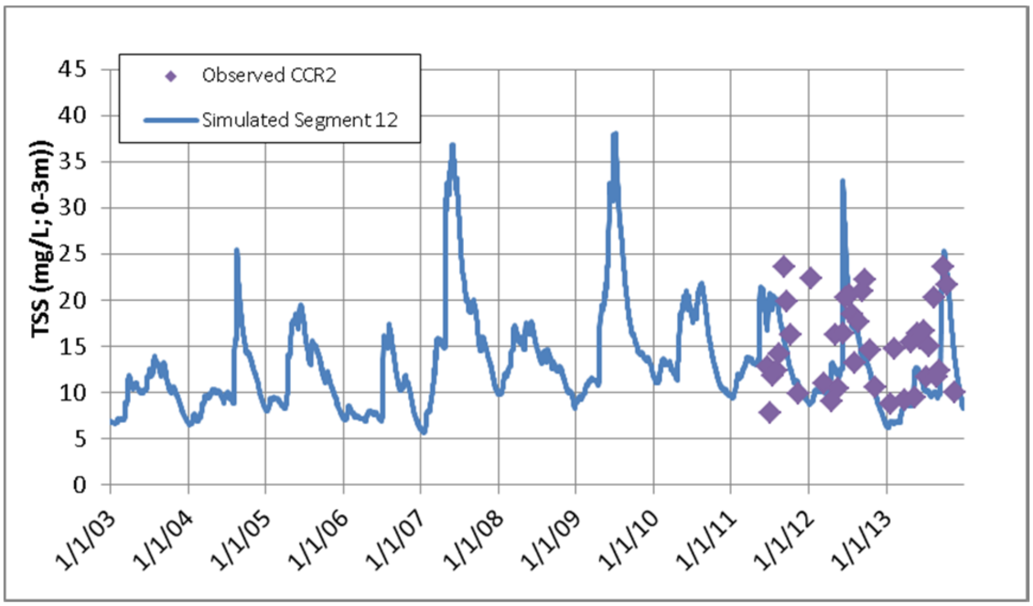
2. Comparing field data of light extinction to model prediction of light extinction would be an important check on predicting light transmission as it affects algae growth.

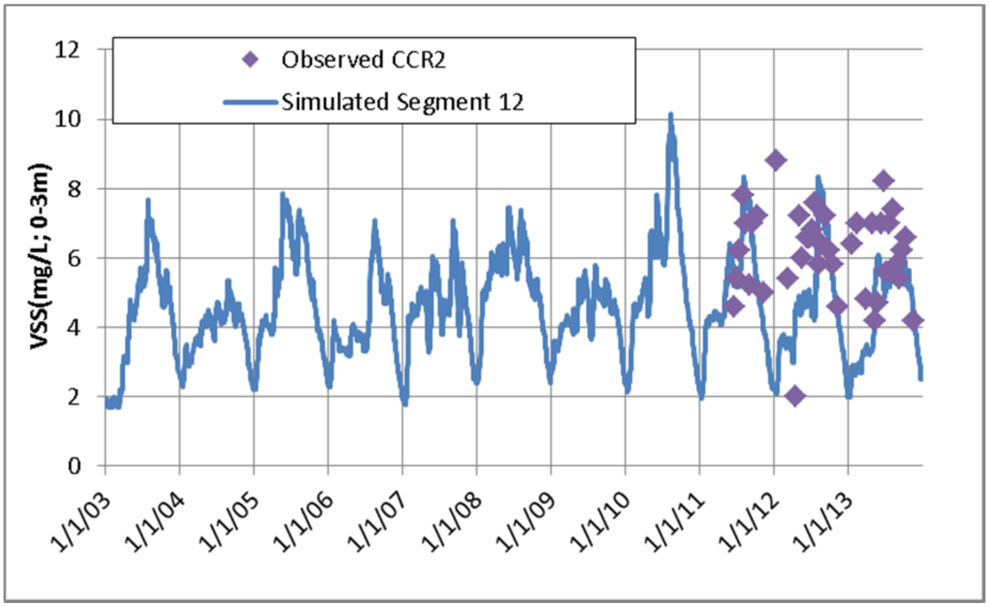
Thanks for this comment. It was valuable to make this comparison. The draft calibration model was exhibiting greater light transmission than was observed in the field. Extinction values for algae, organic matter, and ISS were adjusted to better match observations. The resulting extinction rate at 1 m is plotted against the observed extinction rate in the reservoir in the figure below. Note, modeled extinction rates for 2 m, and 3 m show similar results to 1 m. A reasonable general match is now seen in model output.



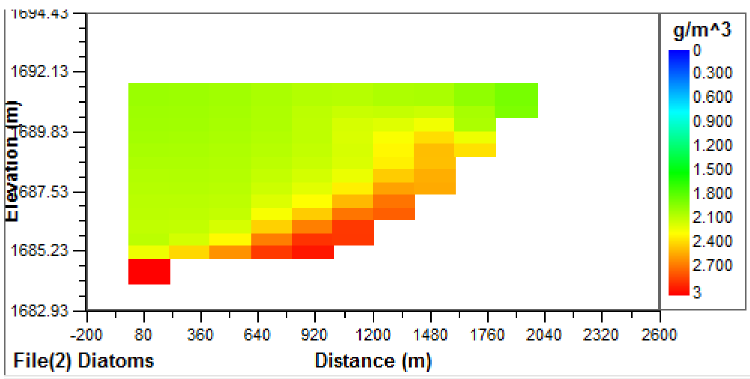
3. With the large amount of particulate organic and inorganic matter in the reservoir, a comparison of TSS and VSS (which would be LPOM, RPOM, and total algae in the model) could affect the model's ability to predict dynamically the light extinction coefficient. This is especially true since the average inflow of ISS from Cherry Creek is over 40 mg/l with a peak of 1600 mg/l.

Thanks for this comment. TSS and VSS data in the reservoir are only available for the last few years of the simulation period. It was useful to compare observed and simulated TSS and VSS for 2011 through 2013. As a result of these comparisons, two ISS groups were used and settling rates were adjusted for the ISS and POM to better match the range of observations. These adjustments also supported improving simulation of light extinction (discussed in Comment #2). The following plots present ISS and VSS, observed (sampled as a composite of the top 3 m in the reservoir) and simulated (also an average of top 3 meters).

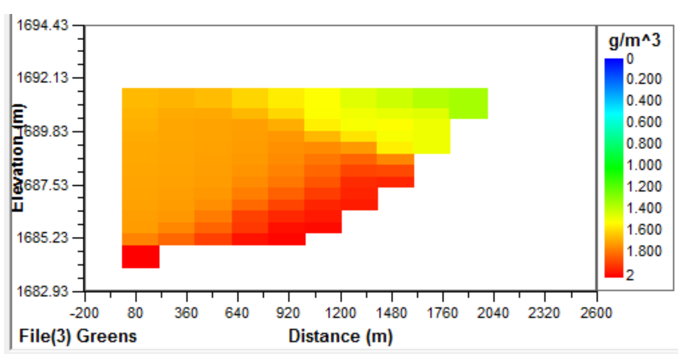




4. The low values of ASAT for the first 2 algae groups of 20 W/m$_2$ seem low. There are cases where algae growth is concentrated at the bottom of the model perhaps by settling and the low value of ASAT. Note the ‘diatom’ group model predicted growth in May of the first year with the unusual growth at the bottom of the reservoir (this is common in most years).



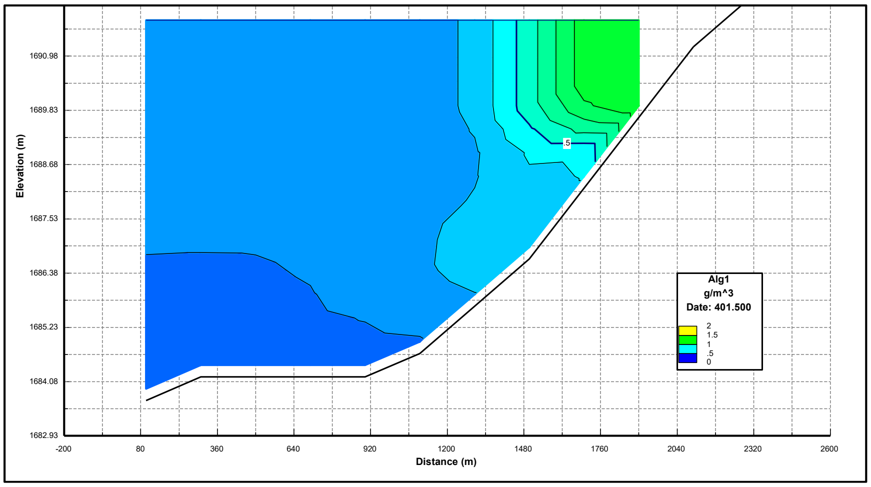
In April of the first year (Day 101.2) for the group called ‘greens’ also showed similar behavior:



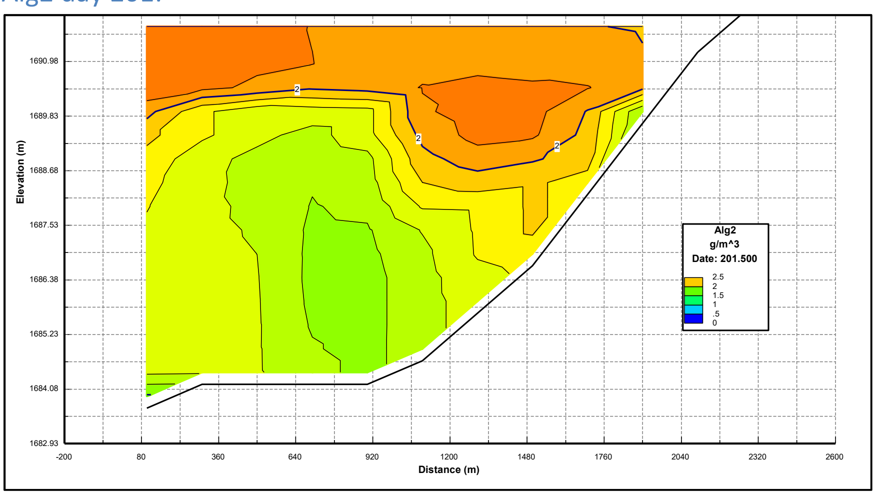
This growth at the bottom may be due to too much light penetration and low values of ASAT or due to inflow density currents. I would encourage animating the various water quality parameters to make sure behavior is as intended.

Animations have been reviewed as part of the updated calibration. The low ASAT values for algal groups 1 and 2 have been increased for the refined model. The algal growth occurring at depth in the draft output is no longer observed. Examples of algal spatial patterns for all 5 algal groups are presented below.

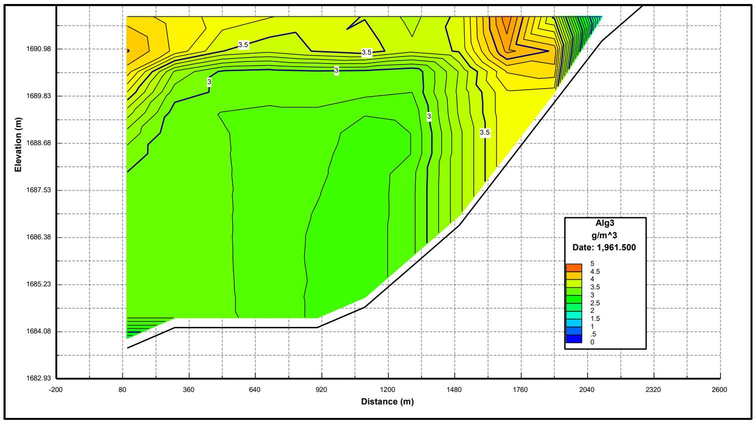
Alg1 day 401:



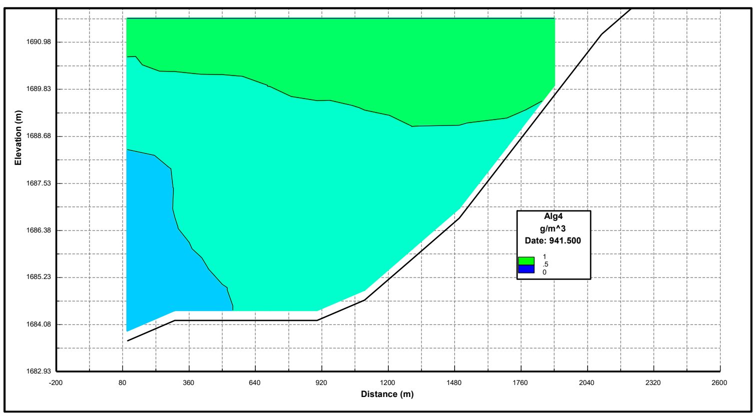
Alg2 day 201:



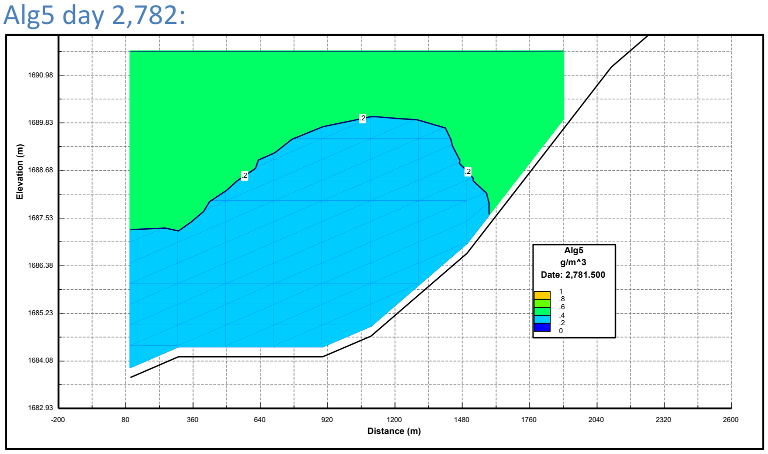
Alg3 day 1,962:



Alg4 day 942:



Alg5 day 2,782:

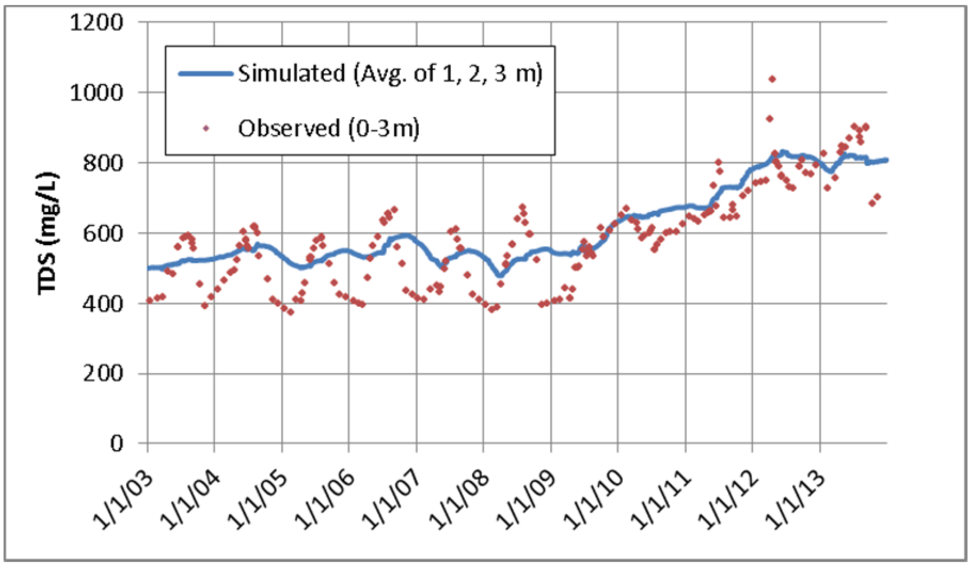


5. pH was not modeled in this simulation but it can be a useful state variable since it helps verify aerobic sediment processes by closing the loop on a C balance. This may require looking at the boundary conditions for TIC and alkalinity that are currently constant over time.

For the current modeling effort, simulation of pH has not been added. Boundary condition data for alkalinity were not available for input (data only collecting in 2001, prior to modeled years). TIC data are not available for any years. Likewise, pH data were only collected on inflows starting in 2008. Attempts to simulate pH could be considered for future model updates.

6. The model computes TDS as a state variable. It was mentioned an increase in TDS has occurred over the last few years as a result of increased TDS from the tributaries. Were there comparisons to field data?

The following figure compares simulated and observed TDS in the reservoir. The increase in 2008 is apparent in the modeled results as well. Note: The same relationship (0.67*Sp. Cond.) used to convert observed conductivity to TDS for model input was used to convert in-reservoir observed conductivity to TDS for this comparison. Also note that specific conductivity data were not collected on the inflows until 2008. Inflows from 2003-2008 assumed in-reservoir concentrations at the time, likely damping the observed seasonal pattern.



7. Aeration input (mass of O2 delivered by the aerators) was calibrated to match dissolved oxygen profiles. A check should be made on the actual amount of oxygen delivered by the aeration system and whether the calibrated amount added seems reasonable.

The aerators provide 200 to 250 cubic feet of air per minute (or 8,155 cubic meters per day). Assuming a density of air of 0.93 kg/m^3 at an altitude of 5,500 ft at 90°C (error on the side of high temperature to avoid overestimating the resulting mass), this corresponds to 7,584 kg of air per day. Assuming 23% oxygen, this equates to 1,744 kg oxygen per day. Since the aerators are distributed over four reservoir segments, this equates to a maximum potential of 436 kg/day of oxygen per segment, assuming an even distribution. The gradient driving oxygen out of the bubbles decreases with increasing elevation in the reservoir. Further, contact time is low in this relatively shallow system. A total of 200 kg/day of oxygen per segment was used in the modeling. This is a little less than half the maximum potential. The effect of this directly-added oxygen is minimal in the modeled response, as might be expected based on the depth of the reservoir.

8. During the fish kill in 2012 (?), C, N, and P were added to the aerobic sediments during this period. The amounts added should be checked to see if they are reasonable based on observations.

For the fish kill in 2012, it was assumed that 90% of the fish settled to the bottom of the reservoir, corresponding to roughly 5,000 fish. It was assumed that the average weight of the fish was 0.2 kg/fish, resulting in ~1,000 kg of settled dead fish. Assuming 850 acres of bottom surface (3.4E6 m^2), this corresponds to 0.29 g OM per square meter. Assuming ~50 carbon:OM and the Redfield ratio (C:N:P = 106:16:1), the following increases in sediment compartment concentrations were applied: Carbon +0.14 g/m^2, Nitrogen +0.02 g/m^2, Phosphorus +0.001 g/m^2.

9. Zooplankton data collected in later years of the model calibration should be compared to field data for zooplankton during these years if zooplankton are used in the model. Even though there have been hypotheses for zooplankton productivity throughout the period of model calibration, the model should have zooplankton during the entire period of the model. It may be that some of the mortality functions of zooplankton (or for that matter algae) may be time dependent but are represented in the model as static values.

The recalibrated model uses consistent zooplankton setting and two zooplankton groups throughout the modeled period. The time-varying zooplankton effect has been removed. Additionally, comparisons of observed and simulated zooplankton biomass and included in the model documentation.

10. In addition to the extensive model-data comparisons presented (profiles and time series graphs), animations, contour plots and velocity vectors plots may be helpful to visualize the model predicted behavior of the reservoir.

Agreed. Additional output visualization tools were used in model recalibration.

11. The zero order and first order models are used for sediment impacts. Since the zero order SOD model is not predictive but varies only by temperature, one may want to experiment (if there are time/resources available) with the Version 4 model with the fully predictive SOD model. This will require turning off the zero and first order models.

Unfortunately, there is not sufficient time and budget to allow for simulation of the sediment diagenesis in Version 4 that you provided at the June 22 meeting. For reasons discussed in comment response 17, this is expected to be an important part of future model refinements. That said, the current version of the model is considered a useful tool to help the authority improve its understanding of the system and direct future water quality management planning.

12. Some documentation should be provided for the high ratio of refractory to labile organic matter coming into the model since it is currently set at 10% labile and 90% refractory.

Degradability of the organic matter entering the reservoir has not been measured to our knowledge, so the assumption is largely speculative, based on the expected character of the inflowing organic matter.

The organic matter entering the reservoir from the Cherry Creek watershed is expected to be characterized more by allochthonous organic carbon than autochthonous. A literature review presented by Hendrickson et al., (2002) states that the biodegradable percentage of organic matter in rivers dominated by allochthonous organic carbon has been observed between 7% to 25%, citing Sondergaard and Middelboe (1995) and Volk et al., (1997). This is attributed to the more refractory nature of more-humic autochthonous organic matter. Further, McLaughlin and Kaplan (2013) found a range of 8 to 17% labile organic matter in stream samples from storm runoff and baseflow condition (note: McLaughlin and Kaplan (2013) identified a higher fraction of "semi-labile constituents" [30 to 55%], noting a category between labile and refractory).

Billica and Oropeza (2009) report findings of humic substances dominating throughout the watershed in the Upper Cache la Poudre and Big Thompson River watersheds in northern Colorado. Those watershed samples included higher elevation runoff and wastewater treatment plant effluent.

We have seen other applications of W2 assume a 50-50 type of split on labile and refractory, often without clear justification, though such an assumption might be appropriate for some systems. A simulation applying a 50-50 labile-refractory split for inflowing organic matter was also performed to assess sensitivity to this assumption. The resulting chlorophyll *a* concentrations were only minimally different. The in-reservoir total organic carbon concentrations decreased, due to less refractory OM. Use of the 10-90 split provided a better match to the 2014 in-reservoir average TOC data. Based on this limited sensitivity and indication of in-reservoir TOC concentrations from the 2014 data, the 10-90 split was kept in the model. Unfortunately, TOC data are not available prior to 2014.

Billica, J.A. and J. Oropeza. 2010. 2009 Horsetooth Reservoir Water Quality Monitoring Program Report. Prepared for the City of Fort Collins Utilities. September 13, 2010.

Hendrickson, J., Trahan, N., Stecker, E., and Ouyang, Y. 2002. TMDL and PLRG Modeling of the Lower St. Johns River Tech. Report Series Volume 1: Calculation of External Load, May 2002. Pgs 13-15.

McLaughlin, C., and L. A. Kaplan (2013): Biological lability of dissolved organic carbon in stream water and contributing terrestrial sources. *Freshwater Science 32(4). Pgs 1219-1230*.

Sondergaard, M. and M. Middelboe. 1995. A Cross-System Analysis of Labile Dissolved Organic Carbon. Marine Ecology Progress Series 118. Pgs 283-294.

Volk, C.J., C.B. Volk and L.A. Kaplan. 1997. Chemical Composition of Biodegradable Dissolved Organic Matter in Streamwater. Limnology and Oceanography 42(1). Pgs 39-44.

13. The model grid bathymetry orientation angles are off by 180 degrees. This may affect how the lake responds to the wind.

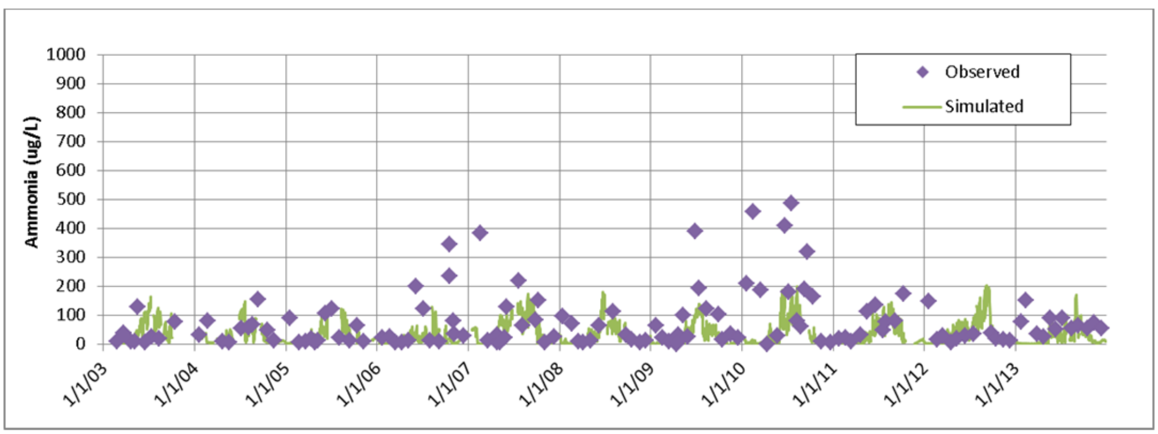
Thanks! The grid orientation has been corrected. Because the error was a 180-degree error, and because of the shape of the reservoir, there were no significant changes to the simulation results when this change was made.

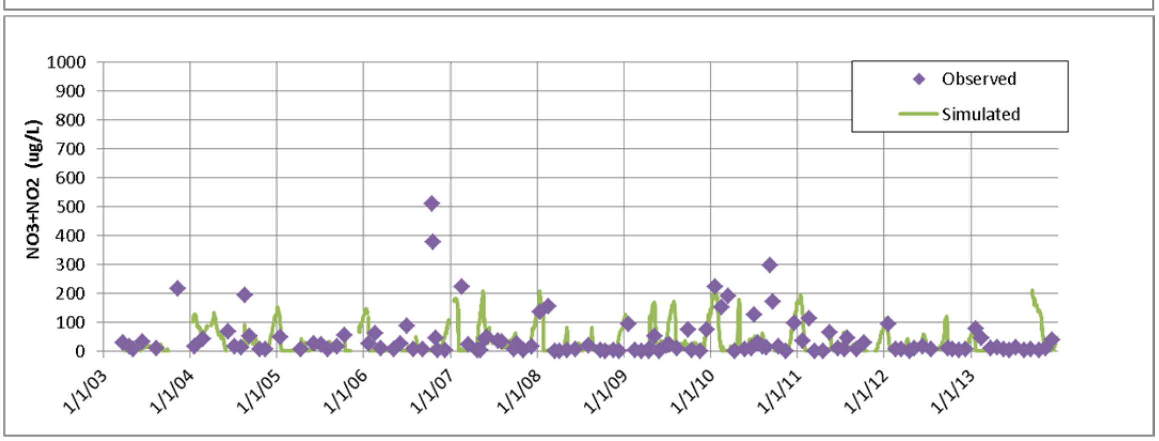
14. Since biovolume species data exist, it would be useful to compare for different seasons model predicted species composition even though the groups may not be exactly aligned with the biovolume species data.

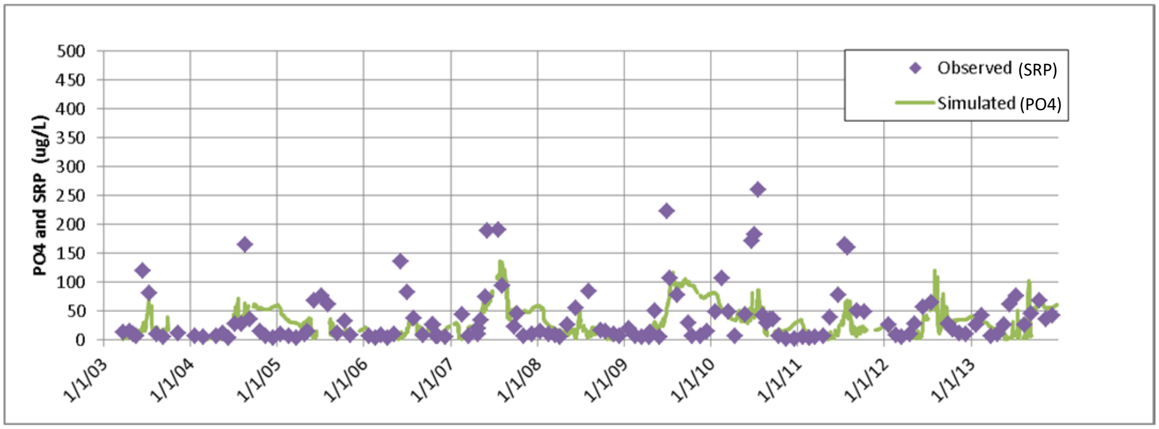
Because the species data do not separate consistently into the largely temperature-response-designated algal groups, a species-by-species plotting of biovolume response relative to algal groups is not expected to provide much additional understanding for the effort. Data show several species can be observed in significant quantities at very different temperatures in different years. This overlap in algal group response was considered reasonable considering the complexity of the observed record and the primary objective of simulating chlorophyll *a*. An exception to this is summer blue-green algae group, simulated in the model as a distinct group. The observed biovolume data from these algae were compared to the simulated biomass as presented in the documentation. Further, the total observed algal biomass was also plotted against the simulated algal concentration as presented in the model documentation.

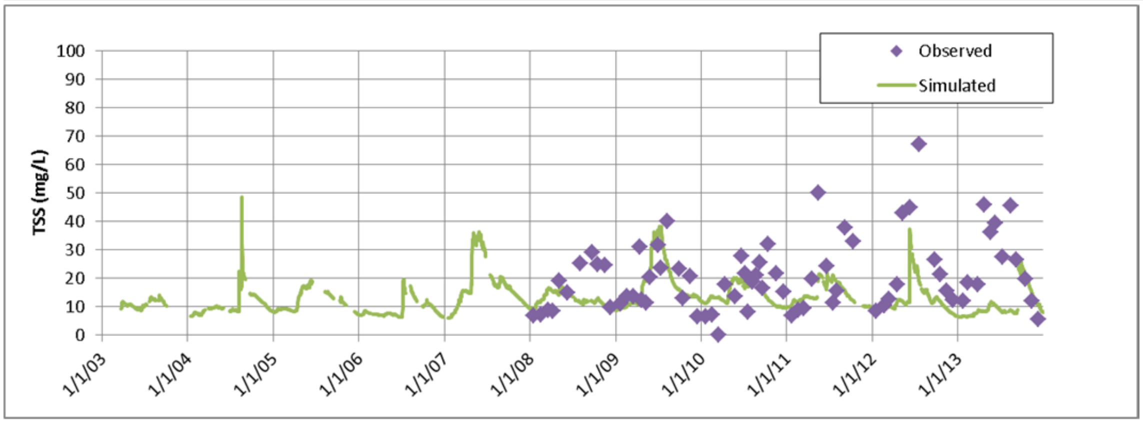
15. Since field data are collected at the outlet to Cherry Creek Reservoir, model predictions of outlet water quality and temperature could be compared to these field data. This provides a check on selective withdrawal of the model and the reservoir's water quality.

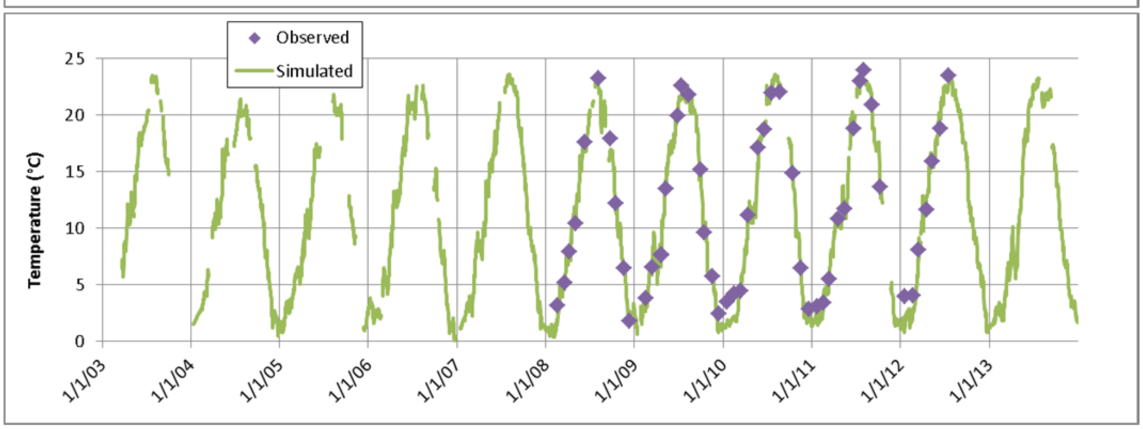
These have been compiled for simulated parameters sampled in the outflow (TSS, ammonia, NO3+NO2, PO4, temperature, and DO).

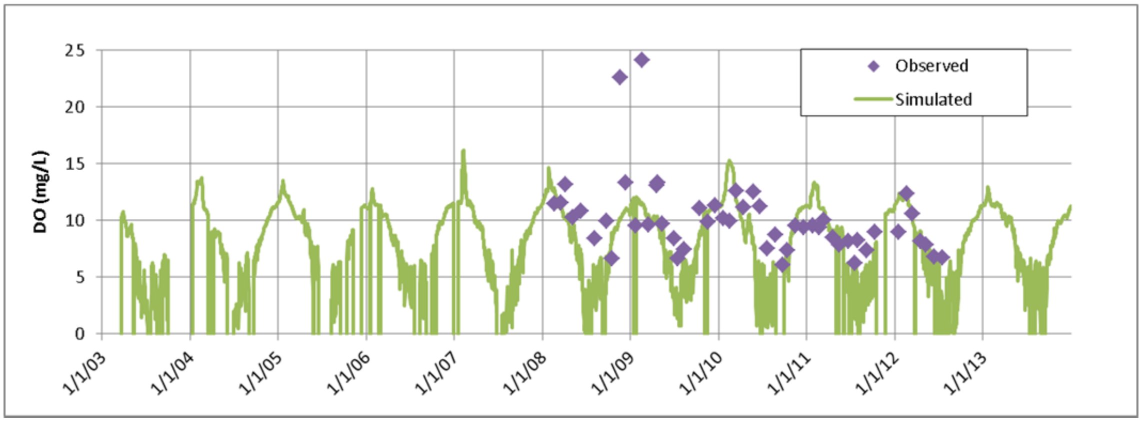





PO4 and SRP (ug/L)
Observed (SRP)
Simulated (PO4)
500
450
400
350
300
250
200
150
100
50
0
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13


TSS (mg/L)
Observed
Simulated
100
90
80
70
60
50
40
30
20
10
0
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13

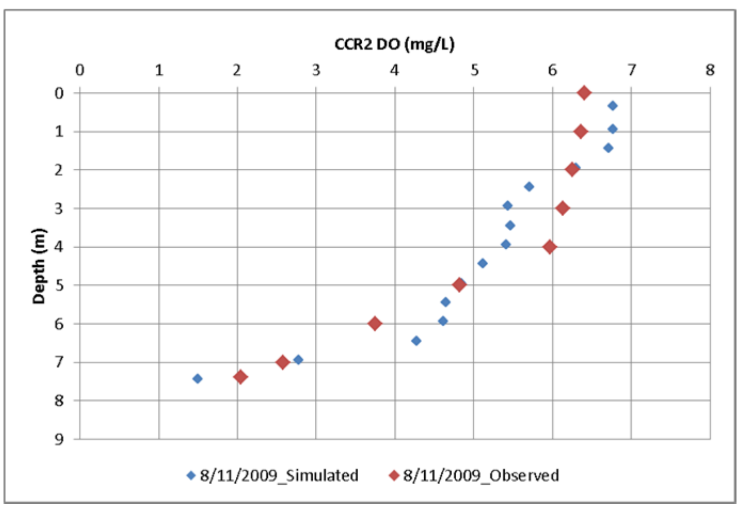

Temperature (°C)
Observed
Simulated
25
20
15
10
5
0
1/1/03
1/1/04
1/1/05
1/1/06
1/1/07
1/1/08
1/1/09
1/1/10
1/1/11
1/1/12
1/1/13



Simulated outflow water quality exhibits reasonable agreement for all of these parameters except DO. The simulated DO is consistently lower through the warmer months. This issue was explored further by adjusting the bottom elevation of the outflow works to simulate possible obstruction but sediment buildup. This did not provide a significant improvement.

The location of outflow sampling is very close to the outflow location, suggesting significant reaeration might not be expected. However, the data suggest otherwise. For example, the outflow observation on 8/11/09 was 7.4 mg/L DO. This is typical of observation at this time of year at the outlet location. A profile in the reservoir at CCR2 was also collected on this date.

There is a reasonable simulation match for DO for this profile, and even the observed data indicate all observations were below 7.4 mg/L. The profile is shown below.



Based on this (and other similar comparisons to observed in-reservoir data) and the well-calibrated thermal simulation, it appears that there must be some aeration between the outlet structure and the outflow sampling location. There is an elevation drop of 10 to 15 ft from the inlet at the bottom of the reservoir and the outflow point. Aeration is apparent in aerial images when water is being released (see example below). It is not clear how much aeration might be expected and whether this can explain the difference in the simulation results. A future refinement of the model could attempt to simulate this reaeration with W2 as a check on this assumption.

Oct 6, 2013 Satellite Image of Outlet Location Showing Some Aeration on Side of Release

16. For performing sensitivity runs with the model, looking at the sensitivity of the model to wind or meterological conditiosn (by varying WSC or using a different meteorologcial file such as from another site) and zero order SOD would be useful.

To give an indication of model sensitivity to wind, one of the sensitivity runs simulated no wind and one turned off the zero-order SOD. Other runs could be conducted in the future.

17. The low dissolved oxygen in the surface of the model during the early years seems to be related to too high SOD during these periods since the largest source/sink is SOD. Changing the reaeration coefficient and/or O2AG may not affect the under-prediction of dissolved oxygen since SOD dominated the oxygen balance (from what I recall seeing in the presentation).

Based on the modeling and review of inflow data and in-reservoir water-quality data, there is no reason to expect a sharp change in SOD in 2010. We have done some additional investigation into the DO data. The magnitude of the difference in DO corresponds roughly to the difference that would be expected if the DO probe was not calibrated to the appropriate altitude (i.e., if mean sea level barometric pressure [which is what is usually reported in weather reports] was input during calibration of the probes without adjustment). We also noted other issues with the data indicating some QAQC problems, challenging the reliability of the some of the data. These include observations of extreme super-saturation (e.g., 180%+) without correspondingly high chlorophyll *a* concentrations (e.g., 15 ug/L). Widely varying DO concentrations at the top at CCR1 and CCR2 (12.5 mg/L DO vs. 6.6 mg/L DO; Note: these are in the same model segment), in spite of comparable chlorophyll *a* (6.4 ug/L Chl *a* and 9 ug/L Chl *a*, respectively). As noted in a previous comment response, there is also uncertainty about observed DO in the outflow data (possibly reflecting reaeration?). These issues are discussed in greater detail in the report.

With all of those concerns with the data noted, it is acknowledged that there is persistent uncertainty in the DO simulation. SOD was reduced by more than half in calibration refinements since the June 22 meeting. The appropriate setting for SOD is difficult to determine given data uncertainty, but the lower SOD provided some improvement in calibration metrics. Additionally, there appears to be induced oxygen demand associated with the aerators that is not being simulated by the model. The model is simulating slightly higher DO at the bottom at CCR2 following start of aeration, but lower DO following aeration can be seen in the observed data. Continuous DO probes have been recommended (bottom, middle, top depths) to support future refinements. Future refinements to address this could involve sediment diagenesis modeling.

18. Since you have made code changes, make sure you are using the exact settings for the Intel Visual Fortran compiler used to compile the release executable. Issues with precision of real numbers can greatly affect the model results.

Following the recommended compiler settings in the release notes for W2 v 3.71, our modified version of the executable was compiled using double precision as the default for real variables, /O2 optimization, and the x64 Debug configuration.

19. It would also be helpful to report mean error in the error statistics in addition to your absolute mean error and RMS since this indicates bias.

We have included mean error to support review for bias.

Dr. Scott Wells provided a letter on September 23, 2015 presenting a second set of comments on the Cherry Creek Reservoir model. This document shows that grid of comments as well as line-by-line responses. Responses were updated to reflect the final calibrated model.

Table 1. Review Comments of Technical Memorandum and Model Files by Subject (page numbers refer to Hydros Consulting, 2015)

<table>
<tr><th><u>#</u></th><th><u>Subject</u></th><th><u>Comment</u></th></tr>
<tr><td rowspan="2">1</td><td>p. 2 “successful at simulating other constituents”</td><td>Perhaps reword to clarify what “successful” means in this context. Is there a success criterion?</td></tr>
<tr><td colspan="2"><u>Response</u>
We will reword this to clarify our meaning.</td></tr>
<tr><td rowspan="2">2</td><td>p. 2 “predicted relationships made sense”</td><td>This statement is subject to interpretation, a more precise wording would be helpful.</td></tr>
<tr><td colspan="2"><u>Response</u>
This is part of the same executive summary sentence noted above. We will reword this to clarify our meaning, while still keeping the text in this section at a high level in terms of detail.</td></tr>
<tr><td rowspan="2">3</td><td>p. 3 “data and modeling show Cherry Creek Reservoir to be very dynamic”</td><td>Clarify by explaining the term “dynamic”</td></tr>
<tr><td colspan="2"><u>Response</u>
This is the first sentence of a paragraph under the heading “reservoir dynamics”. It is followed by six sentences that explain what is meant here by dynamic. It is not clear what additional clarification is being requested.</td></tr>
<tr><td>4</td><td>p. 3 “the reservoir is strongly nitrogen limited through summer months due to high phosphate (bioavailable phosphorus - PO4) loading”</td><td>Model often predicts P limitation. Both light and P limitation were predicted by the model on dates such as (just a few spot checks were made) 3/31/2004, 4/28/2004, 5/26/2004, 6/2/2010, 5/11/2011.

Example of light and P limitation on 9/29/2010 for the spring/fall and winter algae at noon:</td></tr>
</table>

#	Subject	Comment

```
September 29, 2010    Julian Date 2829 days 12.00 hours    Algal group 1 limiting factor

Layer  Depth        4        5        6        7        8        9       10       11       12       13
  5     0.19 L  0.0305 L  0.0343 L  0.0357 L  0.0354 L  0.0337 L  0.0320 L  0.0295 L  0.0252 L  0.0218 L  0.0185
  6     0.62 L  0.5920 L  0.6257 L  0.6404 L  0.6377 L  0.6237 L  0.6085 L  0.5849 L  0.5359 L  0.4890 L  0.4360
  7     1.12 L  0.8781 L  0.8517 L  0.8314 L  0.8359 L  0.8480 L  0.8626 L  0.8819 P  0.8977 P  0.9076 P  0.9200
  8     1.62 L  0.4028 L  0.3673 L  0.3461 L  0.3462 L  0.3573 L  0.3788 L  0.4099 L  0.4800 L  0.5532 L  0.6495
  9     2.12            L  0.1117 L  0.1062 L  0.1029 L  0.1047 L  0.1159 L  0.1322 L  0.1711 L  0.2185 L  0.2879
 10     2.62            L  0.0311 L  0.0298 L  0.0286 L  0.0280 L  0.0324 L  0.0386 L  0.0552 L  0.0772 L  0.1105
 11     3.12            L  0.0086 L  0.0082 L  0.0079 L  0.0074 L  0.0089 L  0.0109 L  0.0172 L  0.0262 L  0.0403
 12     3.62                      L  0.0022 L  0.0022 L  0.0020 L  0.0024 L  0.0031 L  0.0053 L  0.0088 L  0.0145
 13     4.12                      L  0.0006 L  0.0006 L  0.0005 L  0.0007 L  0.0009 L  0.0016 L  0.0029 L  0.0052
 14     4.62                      L  0.0002 L  0.0002 L  0.0001 L  0.0002 L  0.0003 L  0.0005 L  0.0010 L  0.0018
 15     5.12                                L  0.0000 L  0.0000 L  0.0000 L  0.0001 L  0.0002 L  0.0003 L  0.0007
 16     5.62                                L  0.0000 L  0.0000 L  0.0000 L  0.0000 L  0.0000 L  0.0001 L  0.0002
 17     6.12                                          L  0.0000 L  0.0000 L  0.0000 L  0.0000 L  0.0000 L  0.0001
 18     6.62                                          L  0.0000 L  0.0000 L  0.0000 L  0.0000 L  0.0000 L  0.0000
 19     7.12                                                    L  0.0000 L  0.0000 L  0.0000 L  0.0000 L  0.0000
 20     7.62                                                                                  L  0.0000

September 29, 2010    Julian Date 2829 days 12.00 hours    Algal group 2 limiting factor

Layer  Depth        4        5        6        7        8        9       10       11       12       13
  5     0.19 L  0.0305 L  0.0343 L  0.0357 L  0.0354 L  0.0337 L  0.0320 L  0.0295 L  0.0252 L  0.0218 L  0.0185
  6     0.62 L  0.5920 L  0.6257 L  0.6404 L  0.6377 L  0.6237 L  0.6085 L  0.5849 L  0.5359 L  0.4890 L  0.4360
  7     1.12 L  0.8781 L  0.8517 L  0.8314 L  0.8359 L  0.8480 L  0.8626 L  0.8819 P  0.8977 P  0.9076 P  0.9200
  8     1.62 L  0.4028 L  0.3673 L  0.3461 L  0.3462 L  0.3573 L  0.3788 L  0.4099 L  0.4800 L  0.5532 L  0.6495
  9     2.12            L  0.1117 L  0.1062 L  0.1029 L  0.1047 L  0.1159 L  0.1322 L  0.1711 L  0.2185 L  0.2879
 10     2.62            L  0.0311 L  0.0298 L  0.0286 L  0.0280 L  0.0324 L  0.0386 L  0.0552 L  0.0772 L  0.1105
 11     3.12            L  0.0086 L  0.0082 L  0.0079 L  0.0074 L  0.0089 L  0.0109 L  0.0172 L  0.0262 L  0.0403
 12     3.62                      L  0.0022 L  0.0022 L  0.0020 L  0.0024 L  0.0031 L  0.0053 L  0.0088 L  0.0145
 13     4.12                      L  0.0006 L  0.0006 L  0.0005 L  0.0007 L  0.0009 L  0.0016 L  0.0029 L  0.0052
 14     4.62                      L  0.0002 L  0.0002 L  0.0001 L  0.0002 L  0.0003 L  0.0005 L  0.0010 L  0.0018
 15     5.12                                L  0.0000 L  0.0000 L  0.0000 L  0.0001 L  0.0002 L  0.0003 L  0.0007
 16     5.62                                L  0.0000 L  0.0000 L  0.0000 L  0.0000 L  0.0000 L  0.0001 L  0.0002
 17     6.12                                          L  0.0000 L  0.0000 L  0.0000 L  0.0000 L  0.0000 L  0.0001
 18     6.62                                          L  0.0000 L  0.0000 L  0.0000 L  0.0000 L  0.0000 L  0.0000
 19     7.12                                                    L  0.0000 L  0.0000 L  0.0000 L  0.0000 L  0.0000
 20     7.62                                                                                  L  0.0000
```

Alage group 4, the primary algae summer 'group' – summer limitation June 22, 2011 at noon:

```
June 22, 2011    Julian Date 3095 days 12.00 hours    Algal group 4 limiting factor

Layer  Depth        4        5        6        7        8        9       10       11       12       13
  5     0.38 L  0.3099 L  0.2766 L  0.2563 L  0.2419 L  0.2333 L  0.2270 L  0.2252 L  0.2241 L  0.2209 L  0.2165
  6     1.00 P  0.8747 P  0.8552 P  0.8516 P  0.8447 P  0.8443 P  0.8453 P  0.8453 P  0.8461 P  0.8486 P  0.8523
  7     1.50 L  0.4377 L  0.5132 L  0.5566 L  0.5934 L  0.6202 L  0.6382 L  0.6445 L  0.6482 L  0.6548 L  0.6634
  8     2.00 L  0.1170 L  0.1697 L  0.2037 L  0.2266 L  0.2498 L  0.2652 L  0.2718 L  0.2740 L  0.2772 L  0.2807
  9     2.50            L  0.0457 L  0.0688 L  0.0786 L  0.0914 L  0.0999 L  0.1032 L  0.1031 L  0.1033 L  0.1035
 10     3.00            L  0.0121 L  0.0230 L  0.0277 L  0.0337 L  0.0376 L  0.0388 L  0.0381 L  0.0377 L  0.0371
 11     3.50            L  0.0032 L  0.0073 L  0.0099 L  0.0125 L  0.0141 L  0.0146 L  0.0142 L  0.0139 L  0.0135
 12     4.00                      L  0.0022 L  0.0034 L  0.0046 L  0.0053 L  0.0055 L  0.0053 L  0.0051 L  0.0049
 13     4.50                      L  0.0006 L  0.0011 L  0.0016 L  0.0020 L  0.0020 L  0.0019 L  0.0019 L  0.0018
 14     5.00                      L  0.0002 L  0.0003 L  0.0006 L  0.0007 L  0.0007 L  0.0007 L  0.0007 L  0.0006
 15     5.50                                L  0.0001 L  0.0002 L  0.0002 L  0.0003 L  0.0003 L  0.0002 L  0.0002
 16     6.00                                L  0.0000 L  0.0001 L  0.0001 L  0.0001 L  0.0001 L  0.0001 L  0.0001
 17     6.50                                          L  0.0000 L  0.0000 L  0.0000 L  0.0000 L  0.0000 L  0.0000
 18     7.00                                          L  0.0000 L  0.0000 L  0.0000 L  0.0000 L  0.0000 L  0.0000
 19     7.50                                                    L  0.0000 L  0.0000 L  0.0000 L  0.0000 L  0.0000
 20     8.00                                                                                  L  0.0000
```

Summer 2006 P limitation of Algae group 4 except next to the dam at noon:

```
August 30, 2006    Julian Date 1338 days 12.00 hours    Algal group 4 limiting factor

Layer  Depth        4        5        6        7        8        9       10       11       12       13
  6     0.32 L  0.5294 L  0.5136 L  0.5046 L  0.5015 L  0.5124 L  0.5313 L  0.5378 L  0.5397 L  0.5405 L  0.5428
  7     0.89 P  0.9518 P  0.9512 P  0.9513 P  0.9514 P  0.9502 P  0.9483 P  0.9477 P  0.9475 P  0.9474 N  0.9468
  8     1.39 L  0.7955 L  0.8215 L  0.8420 L  0.8481 L  0.8217 L  0.7773 L  0.7605 L  0.7552 L  0.7532 L  0.7487
  9     1.89            L  0.5027 L  0.5306 L  0.5371 L  0.4989 L  0.4500 L  0.4332 L  0.4272 L  0.4251 L  0.4231
 10     2.39            L  0.2644 L  0.2875 L  0.2918 L  0.2593 L  0.2280 L  0.2192 L  0.2153 L  0.2143 L  0.2152
 11     2.89            L  0.1302 L  0.1451 L  0.1486 L  0.1263 L  0.1097 L  0.1066 L  0.1052 L  0.1054 L  0.1070
 12     3.39                      L  0.0711 L  0.0738 L  0.0604 L  0.0518 L  0.0510 L  0.0508 L  0.0515 L  0.0529
 13     3.89                      L  0.0345 L  0.0362 L  0.0289 L  0.0244 L  0.0241 L  0.0243 L  0.0249 L  0.0259
 14     4.39                      L  0.0167 L  0.0177 L  0.0140 L  0.0115 L  0.0114 L  0.0116 L  0.0120 L  0.0126
 15     4.89                                L  0.0086 L  0.0068 L  0.0055 L  0.0054 L  0.0056 L  0.0058 L  0.0061
 16     5.39                                L  0.0042 L  0.0033 L  0.0027 L  0.0026 L  0.0027 L  0.0028 L  0.0030
 17     5.89                                          L  0.0016 L  0.0013 L  0.0013 L  0.0013 L  0.0014 L  0.0015
 18     6.39                                          L  0.0008 L  0.0006 L  0.0006 L  0.0006 L  0.0007 L  0.0007
 19     6.89                                                    L  0.0003 L  0.0003 L  0.0003 L  0.0003 L  0.0004
 20     7.39                                                                                  L  0.0002
```

In many cases there are complex limitation where both N and P limitation occur or where the surface is only N limited. Often throughout the fall and winter – it appears that P limitation is common as a result of having low values of AHSN forcing P limitation in the

<table>
<tr><th>#</th><th>Subject</th><th>Comment</th></tr>
<tr><td></td><td></td><td>model.</td></tr>
<tr><td></td><td colspan="2">Response
The referenced statement from the Hydros report refers to N limitation in summer months. The comment notes a few cases of simulated P limitation in summer months, including an example of the winter algal group (group 1). The commenter continues to make a statement about simulated P limitation in fall and winter. This is not contradictory to the statement referenced about N limitation dominating in summer months.

There are cases in the data where observed phosphorus concentrations dip. There are also cases where observed nitrogen concentrations spike in the summer. As such, there may be times when there is P limitation in the summer, but it is likely infrequent. P limitation may be more common in winter months.

Note: AHSN is discussed further under comment #25.</td></tr>
<tr><td rowspan="2">5</td><td>p.4 “halfing nutrient concentrations in Cottonwood Creek resulted in small simulated increases in chlorophyll a in roughly half of the simulation years. …halving nutrient concentrations increased the relative fraction of PO4 present in the reservoir. As a result, the model simulated increasing growth of nitrogen-fixing cynaobacteria.”</td><td>The overall N:P ratio does not change much when the Cottonwood Creek nutrient levels are halved. The change in N and P limitation in the reservoir is very complex and depends on locations of inputs and timing of inputs as well as parameters for the algae groups. How the N:P ratio was changed by halfing the Cottonwood Creek input and whether that was significant and what levels of cyanobacteria grew in the different years is needed to be shown before reaching the conclusions in the narrative. Also, it was not demonstrated why this only affected half of the years. It is true that one needs to be careful changing the N:P ratios since lowering them significantly can increase the risk of blue-green algae growth.</td></tr>
<tr><td colspan="2">Response
The statement in Hydros’ narrative did consider the cyanobacteria concentrations, which supports the statement. The reduction in the N:P ratio is small, and the effect is small.</td></tr>
<tr><td rowspan="2">6</td><td>p. 5 “the model is not currently simulating all of the mechanisms behind the induced SOD effect.”</td><td>Please clarify the mechanisms that are not being simulated.</td></tr>
<tr><td colspan="2">Response
This is described in the model documentation report on pg 17 noting, in particular, effects of increased mixing reducing the diffusive boundary layer.</td></tr>
<tr><td rowspan="2">7</td><td>p. 5 “induced missing”</td><td>Typo: “induced mixing”</td></tr>
<tr><td colspan="2">Response
We will fix this typo.</td></tr>
<tr><td>8</td><td>Nutrients in dam outflow</td><td>Predictions of PO4P outflow concentrations are often greater than</td></tr>
</table>

<table>
<tr><th>#</th><th>Subject</th><th>Comment</th></tr>
<tr><td></td><td>Response to comment 15, page 14, in attachments draft.</td><td>measured data before 2011 indicating systematic error. This should be an important model-data comparison point for assessing model performance. Efforts should be made to reduce systematic error.</td></tr>
<tr><td></td><td colspan="2">Response
This is not the case in the recalibrated model following recoding of the nitrogen fixation.</td></tr>
<tr><td>9</td><td>Dissolved oxygen in outflow

Response to comment 15, page 14, in attachments draft.</td><td>As noted by the model developers, the under prediction of DO concentrations in the dam outflow may be partially due to reaeration occurring in the outlet structure. This hypothesis could easily be tested by a focused sampling survey.

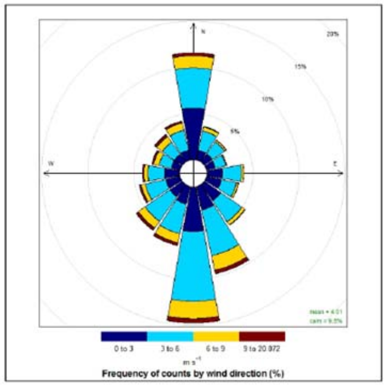
Another cause may be that the model is not simulating enough mixing near the dam leading to greater stratification and lower DO predictions near the bottom or that there is too much oxygen demand occurring in the model (see point 2).</td></tr>
<tr><td></td><td colspan="2">Response
We have not found evidence that the model is undersimulating mixing near the dam. As our response to the first round of comments indicates, the DO in the outflow is higher in cases than DO in the entire profile near the dam. We agree that a study of reaeration at the outfall could help verify this; however, we do not expect this to be an indication of a poor simulation of mixing in the reservoir.</td></tr>
<tr><td>10</td><td>Wind speed/direction data (see Figure 21)</td><td>There seems to be a large number of North/South wind directions in the model meteorological file. Reviewing the meteorological input file, when wind speed equals 0 m/s the wind direction is specified as 0 radians. If these 0 radian values were included in the wind rose diagram (Figure 21), they should be removed.

Also, it is unusual for there to be truly 0 m/s of wind over an hour (the meteorological data frequency was hourly). Of all the hourly data over the 10 year period almost 10% of the wind was set to 0.0, and over 14% of the wind direction was set to 0.

In addition, the average wind speed for the 10 year period was 3.6 m/s. Historical averages for Denver are about 8.7 mph or 3.9 m/s. Hence the 10 year average was about 8% less than the historical average which could have been influenced by the 0 m/s wind values

The wind sheltering coefficient was set to 1.0 for the entire simulation period implying that the wind speed data were not adjusted during model calibration.

We would recommend that the wind rose be superimposed over the reservoir outline to show the predominant wind direction on the reservoir. Fig. 21 is shown below:</td></tr>
</table>

#	Subject	Comment
		 Figure 21. Wind Rose, 2003-2013, KAPA Data from 10 m Our analysis of wind data at Centennial Airport (KAPA) from 1980-2013 showed a very different wind rose than reported in Hydros Consulting (2015):  Since the wind field is critical to modeling this system, this discrepancy should be investigated.

Response:

After review of the data, Hydros identified discrepancies with the data workup developed by Dr. Wells, including differing date range, consideration of missing data, and graphical presentation of results. Following this review, there are no concerns with this data input to the model. Further detail is provided below:

Part 1: Wind Rose

Hydros presented a wind rose in the modeling report for data from Centennial Airport. The data used for the development of the wind rose were hourly data from January 1, 2003 – December 31, 2013 – the period relevant to the model calibration discussion. Dr. Wells presented a wind rose of wind data from the same source (Centennial Airport) and came up with very different results (Figure 1). We obtained the files used to develop Dr. Wells' wind rose to understand the differences.

- Although the slide presented by Dr. Wells shows two different time periods (1980-2013

#	Subject	Comment

and 2008-2013), the data actually used in the Wells wind rose are from December 4, 1980 through September 15, 1984. It is unclear why data from this much older, <4-year period were used. The raw data file Dr. Wells obtained contained data through July 1, 2013.

- If one graphs the raw wind data from the airport (Figure 2), it is noted that observations recorded prior to ~July 1996 are significantly different. According to our research, this is when the airport (coinciding with a nationwide initiative) modernized their system and started using METAR reporting conventions (See http://www.srh.noaa.gov/msd/note2.html and http://www.nws.noaa.gov/ops2/Surface/overview.htm.)

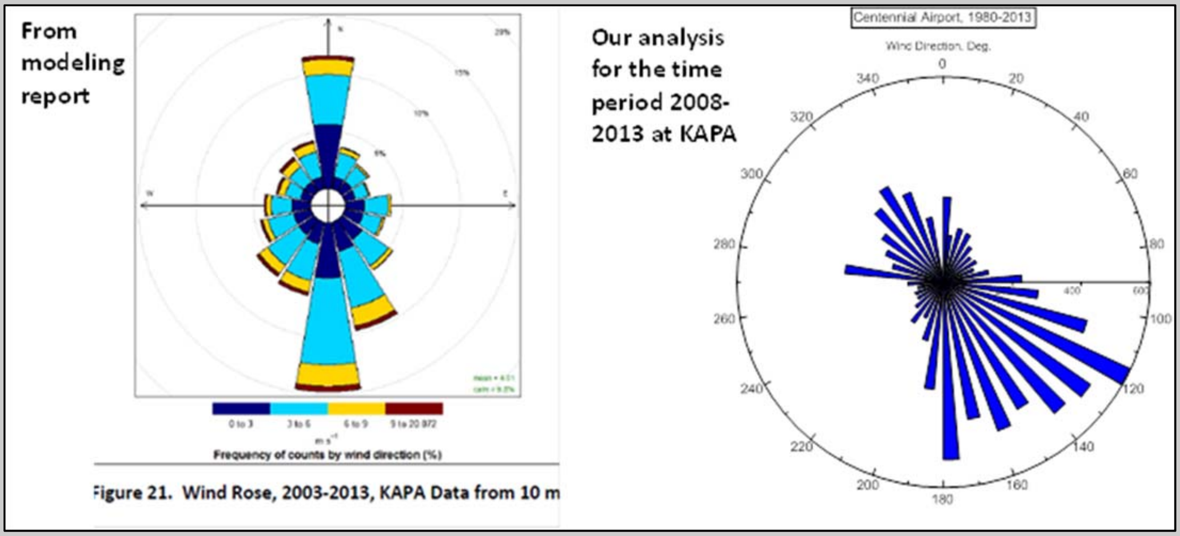


Figure 1: Slide from Wells Presentation, September 24, 2015

#	Subject	Comment

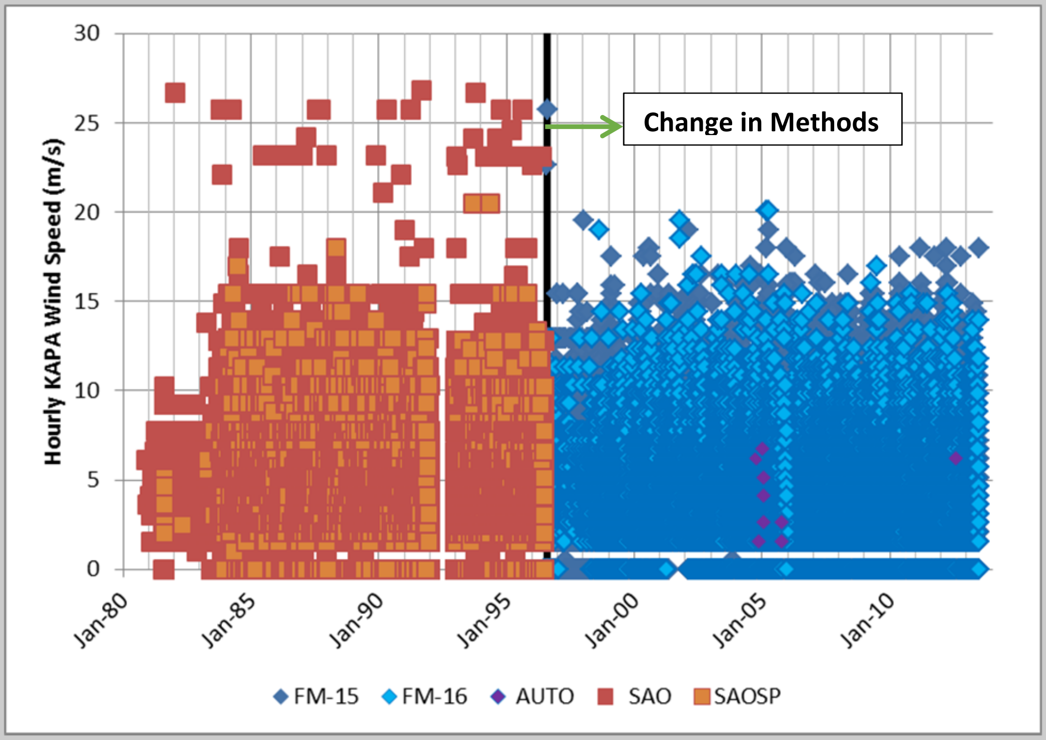


Figure 2: Raw Wind Speed Data from Centennial Airport (KAPA) (12/4/80 – 7/1/13)

- Although Dr. Wells reported to Hydros in an email that he “used hourly data where zero values and 999 values were deleted”, this is not accurate. The data presented in the wind rose by Dr. Wells were not processed to remove any values other than those after 9/15/1984 (according to the file sent to Hydros on 10/6/15).

  The result of keeping the 999 values appears in Dr. Wells’ wind rose as a spike at 279 radians (999-360*2).

  Note that Hydros did not include wind directions listed as 999 for the Cherry Creek Reservoir Water-Quality Model. When a value of 999 occurred in the original raw data file, different actions were taken to adjust wind speed and wind direction, depending on the associated data flag (“calm”, “variable” or “missing”).

- The “slices” used by Wells are not centered on the reported angle. They are aligned on the clockwise-most edge of the “slice”. This results in a visual shift of the wind rose in the counter-clock-wise direction, when compared to the Hydros wind rose (which is centered on the reported angle and is a standard representation).

- The Hydros wind rose uses a 22.5-degree “slice”, while the Wells wind rose uses a 10-degree “slice”. Use of more refined 10-degree “slices” (centered) and the Hydros data, shows more of a south-south-east direction (Figure 3).

#	**Subject**	**Comment**

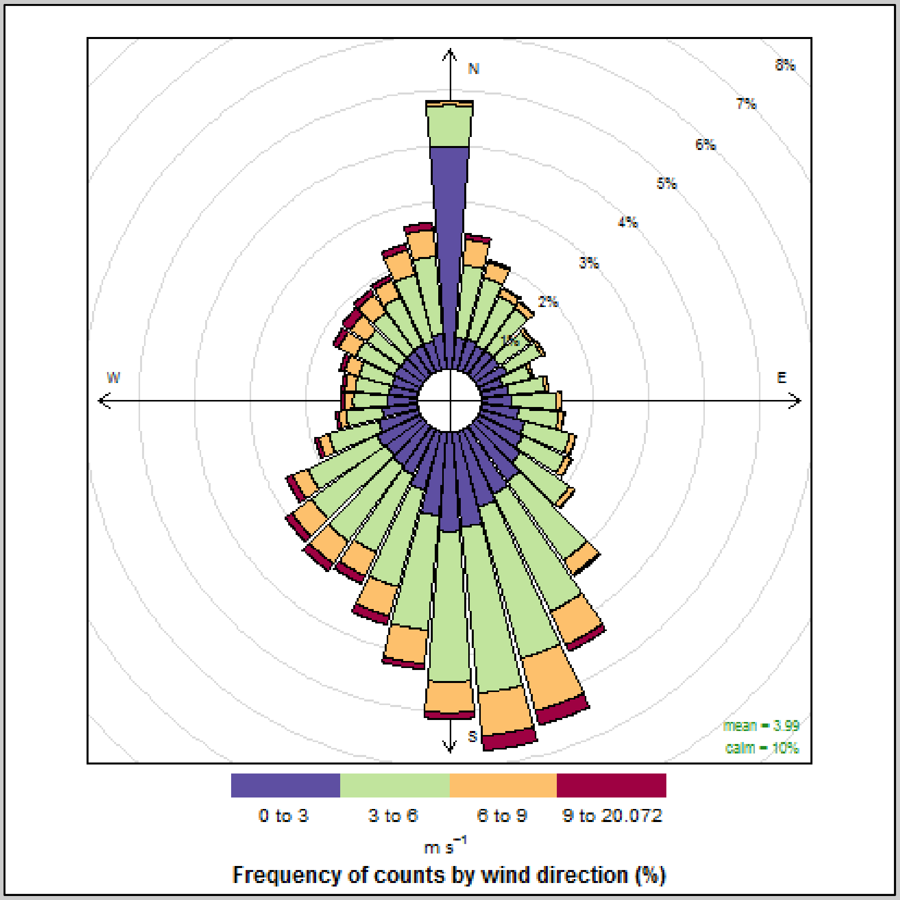


Figure 3: Hydros Data with a 10 Degree Slice (2003-2013)

Summary of the Discrepancy:

- Wells used data from a <4-year period which are at least 30- years old and do not represent the period of calibration (Figure 2).
- Data used in the Wells wind rose includes wind directions noted as 999 directly.
- The "slices" used by Wells are not centered on the reported angle. They are aligned on the clockwise-most edge of the "slice". This results in a visual shift of the wind rose in the counter-clock-wise direction, when compared to the Hydros wind rose (which is centered on the reported angle). Using a smaller 10-degree "slice" (centered) and the Hydros data, prevailing winds from a south-southeast direction are observed.

Actions to Consider:

Some additional "fine tuning" of the wind data could be made for cases where data are not complete. Our current processing of the data does result in a higher number of records showing the wind coming from the north (zero radians). However, much of these data are at very low wind speeds when the wind direction is much less important (See Figure 3). Also, we did make the

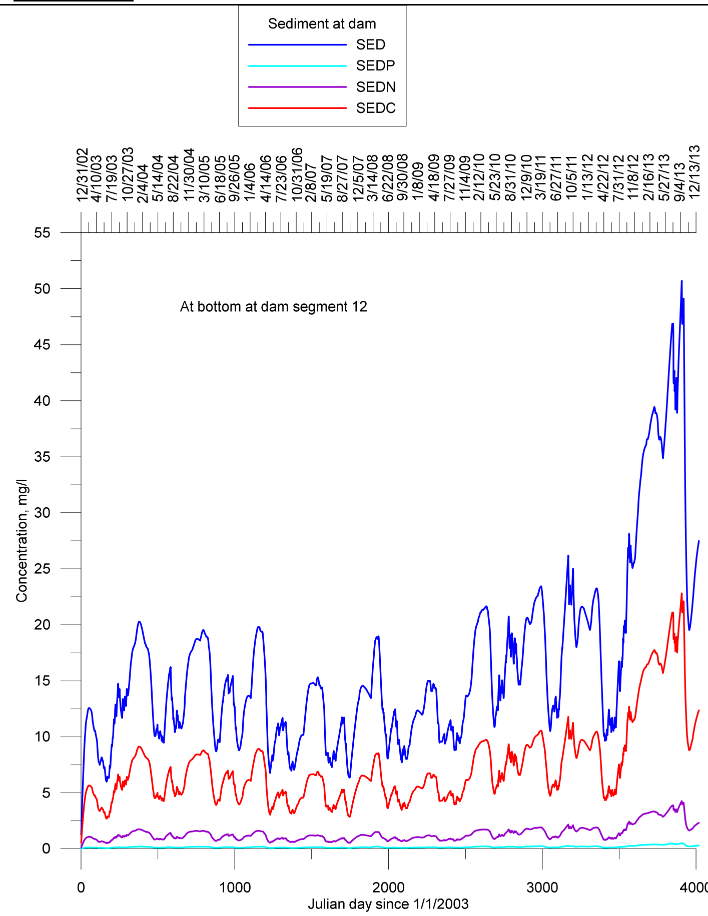
#	Subject	Comment
	assumption that calm conditions could be represented by zero m/s since wind speeds were less than the measurement detection limit of the anemometers. Perhaps a better solution is to set the values at ½ the detection limit. Interpolating the wind direction for cases where conditions were "variable" may be a better approach (over assigning zero radians). However, assigning zero when conditions are "variable" is essentially assigning the opposite direction from the prevailing winds, and can therefore result in variable direction as the model interpolates to zero and back to an observed direction. Note that there are no "right" assumptions and it is unclear if making changes will significantly affect model results or conclusions. *Part 2: Average Wind Speed* Wells notes that "the average wind speed for the 10 year period was 3.6 m/s." We assume he is referring to wind speeds used by Hydros, although it is for an 11-year period (2003-2013). He also notes that the "historical averages for Denver are about 8.7 mph or 3.9 m/s." He did not document the source of data used for "Denver" (DIA? KAPA?), nor the time period. If Dr. Wells is referring to KAPA data and using the period of record, his numbers would show a bias on the high side due to changes in measurement methods described above.	
11	Attachment B: Temperature Calibration: Observed and Simulated Results, Temperature Profiles, CCR2 and CCR3	The vertical temperature profiles indicate that not enough vertical mixing is predicted during the warmer months (June to August) for the years 2005 to 2007. For later years the predictions appear better. This is possibly due to inadequate wind mixing. A re-examination of wind data may indicate that the wind and wind direction were biased toward being too low. Increasing the wind sheltering coefficient above 1.0 during these years could also be used to explore if this fixes these temperature profiles.
	Response: Dr. Wells suggests adjusting the wind sheltering coefficient above 1.0 in certain years to improve the calibration. Hydros strongly feels that one does not adjust this coefficient temporally without justification purely to "match the data". We do not know of a reason why the wind would suddenly increase over what was measured, but only for certain years. Nor are we aware of changes in wind measurement methods in the middle of our calibration period. This could result in "trying to match data but not for the right reasons." Note that the temperature calibration statistics for the Cherry Creek Water-Quality Model are well within the range used by the CE-QUAL-W2 model managers making these comments (i.e. AME within 1 degree C; Wells, et al., 2008), including the results for 2005 through 2007 noted above.	
12	Attachment C: Dissolved Oxygen Profiles: Observed and Simulated Results	Model predicted dissolved oxygen concentrations show greater stratification than data during June through August periods for the years 2005 thru 2008 and the year 2013. This suggests that not enough vertical mixing is simulated during these periods (see comment above regarding temperature profiles) and the model may over predict the contribution of sediment anaerobic nutrient release.
	Response See comment response above regarding our thinking on adjusting input met data selectively. We discuss in the report that the DO simulation continues to be an area of uncertainty. That is why we	

#	Subject	Comment
	have proposed continuous DO probe data collection and checking of DO sampling procedures to improve system understanding before adjusting the model.	
13	Short wave solar radiation absorption coefficient	BETA, or the short wave solar radiation absorption at the surface, was set to a value of 0.1. This means that only 10% of the solar spectrum is absorbed in the surface layer of 0.5 m or less. A typical value is set between 0.3 and 0.6. This low value suggests some other component of light extinction (such as light extinction due to algae, inorganic suspended solids, particulate organic matter) is being over-predicted (see comment #14).
	Response BETA is set at 0.45 in the final calibrated model.	
14	Algal light extinction coefficient	The algal light extinction coefficient for the 4 algal groups were set to 0.4, 0.3, 0.35 and 0.35 m^{-1}/gm^{-3}, respectively. Model default value is 0.2 m^{-1}/gm^{-3}. These relatively high values may have led to the short wave solar radiation coefficient (Beta) to be calibrated at a relatively low value (see comment #13), and could cause the effect of algae concentrations on light penetration to deeper parts of the water column to be over predicted.
	Response Algal light extinction values are set between 0.1 and 0.3 in the final calibrated model.	

15	August 2012 fish kill and additions of C, N, and P to first order sediment – no addition of organic matter	The model code only added C, N, and P, but did not add organic matter to the first order sediment model. Hence, there was no addition to the oxygen demand on the sediment as a result of the fish kill.
		
		To account for the increase in organic matter in the first order sediment compartment due to the fish kill, an additional line of code is needed in 'w2_37_win.f90'. The increase in N, C, and P appears to be accounted for, but to simulate the increased DO consumption caused by the fish kill an additional line is needed as shown below:
		
		`IF(ONCE <= 0.5) THEN`
		` IF(JDAY >= 3514.0) THEN`
		`     SEDB = BADJ/DAY`
		`     DO I=1,IMX`
		`      DO K=1,KMX`
		`          IF (SEDC(K,I) > 0.0) SEDC(K,I) = SEDC(K,I) + CPLUS`
		`          IF (SEDP(K,I) > 0.0) SEDP(K,I) = SEDP(K,I) + PPLUS`
		`          IF (SEDN(K,I) > 0.0) SEDN(K,I) = SEDN(K,I) + NPLUS`
		`          IF (SED(K,I) > 0.0) SED(K,I) = SED(K,I) + OMPLUS` **← New line of code required**
		`      END DO`
		`     END DO`
		`     ONCE = 1.0`
		` END IF`
		` END IF`
		
		OMPLUS would be the increase in organic matter of the fish in units of g/m^3.

	Response: OMPLUS has been added to the recoding.	
16	August 2012 fish kill:	The fish kill in August 2012 was represented as a new source of organic

#	Subject	Comment
	New organic matter, burial rate change, and errors in added C, N, and P p. 35, 36 Fish kill "Burial rates were also decreased somewhat, starting after the fish kill in 2012." The model report states that they added "Carbon +0.14 g/m², Nitrogen +0.02 g/m², Phosphorus +0.001 g/m²."	matter in the lake even though it is really just a translocation of the organic matter from one pool to another. Hence, the fish organic matter was not a "new" source. The added C, N, and P from the fish kill were very small compared to the existing first order sediment pool at the bottom of the reservoir. The amounts added to all of the model cells were +0.14 g/m^3 C, +0.02 g/m^3 N and 0.001 g/m^3 P. In the report the amounts were reported in g/m^2, but they added these as g/m^3, hence what the report should state is they added +0.07 g/m^2 C, 0.01 g/m^2 N and 0.0005 g/m^2 P which is half of what they computed. (If they had wanted to add Carbon +0.14 g/m^2, Nitrogen +0.02 g/m^2, Phosphorus +0.001 g/m^2, then they would have had to add +0.28 g/m^3 C, +0.04 g/m^3 N and 0.002 g/m^3 P.) The figure below shows the sediment organic matter near the dam over the 10-year simulation at the bottom. For SEDC, at the start of August 2012, bottom concentrations ranged from 4.5 to 9 gC/m3. Hence, the additional 0.14 g/m3 added between 1.5% to 3% to the bottom C pool. Similarly for the N pool, for SEDN, at the start of August 2012, bottom concentrations ranged from 0.85 to 1.65 gN/m3. Hence the additional 0.02 g/m3 added between 1.2% to 2.3% to the bottom N pool. Similarly for the P pool, for SEDP, at the start of August 2012, bottom concentrations ranged from 0.1 to 0.21 gP/m3. Hence, the additional 0.001 g/m3 added between 0.5% to 1% to the bottom P pool. This impact then was minor. Sediment dynamics were significantly affected by the change in the sediment burial rate. There was no explanation as to why this was done. The impact on sediments is seen in the figure below as a sharp increase in organic matter after August 2012 since the burial rate decreased significantly from 0.02 day^{-1} to 0.007 day^{-1}. This directly affected C, N, and P nutrient release from the sediments after that date until the end of the model simulation and it affected not only the newly added fish biomass but all organics deposited in the system. It is unclear why all other organics in the system would be affected by this changed burial rate.

<table>
<tr><th>#</th><th>Subject</th><th>Comment</th></tr>
<tr><td></td><td></td><td>


The nutrient levels predicted in the model for 2013 seem to be too high as a result of this change as shown below for SRP:

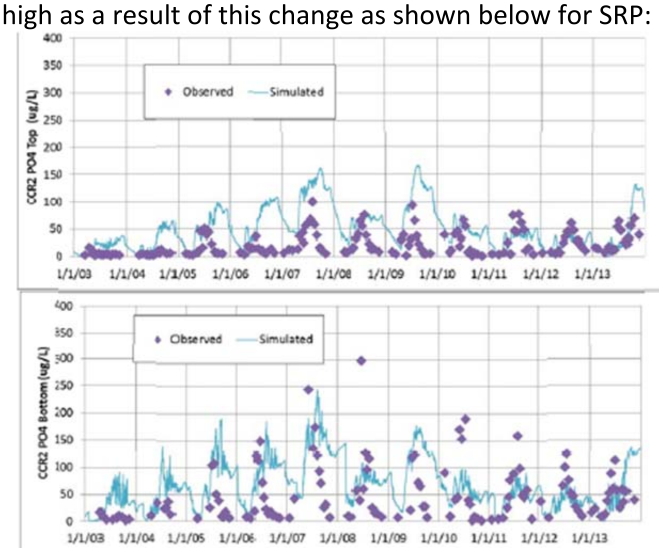
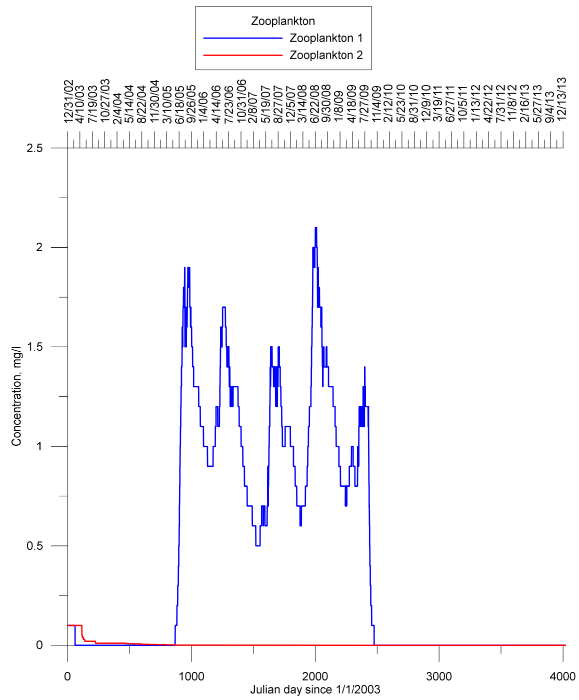


Figure 48. Simulated and Observed Phosphate Concentrations at CCR2, 2003-2013
</td></tr>
<tr><td></td><td colspan="2">Response:
It is not clear where the quoted term “new” source is located in the Hydros technical</td></tr>
</table>

#	Subject	Comment
	memorandum. The model does not track fish tissue in the water column and also does not track effects of a fish kill, including delivery of organic matter to the sediment surface during such an event. Original simulations underestimated chlorophyll a response after the fish kill, so it was hypothesized that the organic matter delivered to the bottom of the reservoir may have been a source of nutrients for the observed algae. This is clearly presented as a hypothesis with associated uncertainty in the technical memo. Our misunderstanding of the units for SEDC came from the statement in the CE-QUAL-W2 user manual that "[SEDCI] specifies the initial *concentration(s)* for the 1st-order sediment compartment and its behavior is exactly the same as for setting the initial concentrations of any of the water column state variables, except that it is in units of mass per surface area or g/m2." Based on this, we assumed the units to be g/m2. As noted in the comment, our error resulted only in an under-estimation of potential load to the sediment surface. The final calibrated model reflects this change to input in terms of g/m3. The burial rate was reduced as part of this adjustment to reflect the fact that the fish bodies might not be buried and lost from the first-order compartment as quickly as POM landing on a flat sediment surface. Again, this is presented as a hypothesis. It is recognized that the burial rate would not continue to be lower in the long term. A limited duration of the effect was added to the recoding in the final calibrated model to limit the duration of the effect of the decreased burial rate. Further, there was no easy way, short of major recoding to track the fish tissue separately, to apply the burial rate adjustment to only the fish tissue.	
17	Settling rate for particulate organic matter (POMS)	The settling rate for particulate organic matter (POMS=0.05) was set to a rather low value of 0.05 m/d. If this value is too low, the oxygen consumption and nutrient release due to the decay of organic matter in the water column (rather than the sediments) may be exaggerated.
	<u>Response:</u> The POMS rate of 0.05 m/d is well within the range of the values reported for detritus in the CE-QUAL-W2 v3.71 manual (0.001 to >20 m/d). The value was lowered from the draft calibration to improve the simulation of volatile suspended solids in the water column, as described in the response to comments in Attachment A of the July 31 Technical Memo. The use of a particulate organic settling rate of 0.05 m/d is consistent with the observations for this system. We also note, in response to the final sentence in the comment, that if the value is too *high*, the oxygen consumption and nutrient release due to decay of organic matter in the water column (rather than the sediments) may be *underestimated*.	
18	Zooplankton	Growth rates of the both zooplankton groups have been set to zero in order to "turn off" these compartments even though these were given initial concentrations and do influence algae in the first year of the simulation. Since only 1 zooplankton group is used in the model, it would speed up model simulation time if the corresponding line in the control file, w2_con.npt, for 'CST ACTIVE' was set to 'OFF'. The model predicted zooplankton near the dam is shown below. This shows the

#	Subject	Comment
		small impact during the first year and the sudden increase from 2005 to 2010 followed by no zooplankton afterwards.



Since zooplankton data exist for the reservoir, it is unclear why these data were not used in the model calibration. For example, zooplankton data are shown in GEI (2012, 2013) where densities of species are itemized. An example of these data are shown below from GEI(2013) below.

Appendix E
Page E-9

Table E-6: 2012 Cherry Creek Reservoir zooplankton.

	2012													
	14-Mar	18-Apr	9-May	22-May	12-Jun	27-Jun	11-Jul	24-Jul	7-Aug	23-Aug	11-Sep	28-Sep	16-Oct	13-Nov
Cladocera														
Bosmina longirostris	210.6	31.1	15.9	28.3	44.6	35.4	16.6	41.1	64.0	93.8	132.5	13.6	3.7	0.2
Daphnia galeata mendotae	–	1.3	2.7	2.3	5.8	9.6	–	19.0	6.7	8.8	8.1	0.1	0.2	–
Daphnia lumholtzi	–	–	–	–	–	–	–	0.4	24.8	0.4	–	–	–	–
Daphnia parvula	–	–	–	–	–	–	–		–	–	–	–	–	–
Daphnia pulicaria	0.3	–	–	–	–	–	–	4.9	1.4	0.9	0.5	–	–	–
Diaphanosoma leuchtenbergianum	–	–	–	–	–	–	–		–	–	–	–	–	–
Copepod														
Diacyclops thomasi	29.1	27.8	20.7	4.1	2.1	2.1	1.1	1.3	0.4	0.7	3.0	3.4	4.0	2.1
Immature instar (copepodid)	66.3	93.1	18.8	12.6	8.5	4.2	0.2	4.9	5.7	5.3	3.2	2.5	0.8	–
Mesocyclops edax	–	–	–	4.4	5.3	3.7	1.4	0.4	1.1	0.2	0.2	1.6	0.4	–
Nauplius	–	61.9	28.3	40.7	81.4	75.2	23.4	121.6	69.0	73.0	78.7	8.4	3.5	13.3
Skistodiaptomus pallidus	7.0	0.7	0.5	3.4	3.7	8.0	0.9	2.7	14.5	4.2	5.0	–	–	0.1
Rotifer														
Asplanchna sp.	1.7	–	–	–	–	–	–	–	–	–	1.8	–	–	–
Bdelloid rotifers	–	–	–	–	–	–	–	–	–	–	4.4	–	–	–
Brachionus angularis	–	–	–	–	–	–	–	17.7	39.8	–	5.3	0.9	–	–
Brachionus calyciflorus	–	–	–	–	–	–	–	–	–	28.8	–	–	–	–
Gastropus sp.	–	–	–	–	–	–	–	–	69.0	–	0.4	–	–	–
Keratella cochlearis	8.4	211.0	262.7	132.7	32.7	29.2	1.3	1.8	17.7	0.9	18.6	–	34.0	105.2
Polyarthra sp.	–	–	–	–	–	–	–	–	–	–	24.3	15.0	–	–
Trichocerca sp.	–	–	–	–	–	–	–	–	–	–	0.4	–	–	–
Total Concentration (#/L)	323.5	426.9	349.6	228.4	184.2	167.4	44.9	215.9	314.0	216.9	286.0	45.5	46.6	120.9
Total Number of Taxa	7	7	7	8	8	8	7	11	12	11	15	8	7	5

Response

Zooplankton settings are applied consistently for the full model period in the final calibrated model; therefore this comment no longer applies.

#	Subject	Comment
19	Evaporation	By not tying in evaporation to the water surface area (the water level), water temperature, and local wind conditions and atmospheric conditions, the current evaporation model used is not predictive. We recommend redoing the evaporation model using the predictive model

<table>
<tr><th>#</th><th>Subject</th><th>Comment</th></tr>
<tr><td></td><td></td><td>within CE-QUAL-W2 so that evaporation impacts can be assessed for management simulations.</td></tr>
<tr><td></td><td colspan="2"><u>Response</u>
The approach taken by Hydros was to directly apply a predeveloped water balance. In future predictive runs with varying water level conditions, evaporation could be calculated in this same way, based on water level, then adjusted slightly, as needed, with an iterative run predicted water temperature.</td></tr>
<tr><td>20</td><td>p. 32 Precipitation</td><td>In future version of CE-QUAL-W2 the user will have an option of making the rainfall a flow rate rather than being dependent on surface area of the water body. Hence, as the water level varies and surface area changes, the flow rate into the reservoir changes.</td></tr>
<tr><td></td><td colspan="2"><u>Response</u>
No response needed.</td></tr>
<tr><td>21</td><td>p. 34 “the zero order sediment compartment simulates anaerobic oxygen demand and internal loading”</td><td>This should be restated as follows: ‘The zero order model simulates uptake of oxygen during aerobic conditions and nutrient release during anaerobic conditions.’</td></tr>
<tr><td></td><td colspan="2"><u>Response</u>
The wording will be changed as suggested.</td></tr>
<tr><td>22</td><td>Aerators

p. 35 200 kg/day/aerator was delivered to each segment

p. 6 Aerator target is DO of 5 mg/l at the bottom</td><td>It is unclear why the maximum 436 kg/day/segment was not used in the model especially if “the effect of this directly-added oxygen is minimal in the modeled response”. An analysis showing the impact of the aerators delivery of oxygen to the reservoir would be helpful.

Since the target was 5 mg/l at the bottom, how much oxygen was necessary to meet that with the aerators? Showing this in the report would be helpful.</td></tr>
<tr><td></td><td colspan="2"><u>Response</u>
The maximum oxygen load was calculated to serve as an upper bound in inputting oxygen addition to the water column through the aerators. It does not seem reasonable to assume that every molecule of O_2 pumped through the aerator would be dissolved into the water column, especially since the reservoir is relatively shallow. This is stated in Attachment A to the July 31 Hydros Technical Memorandum, noting short contact time for this shallow system.

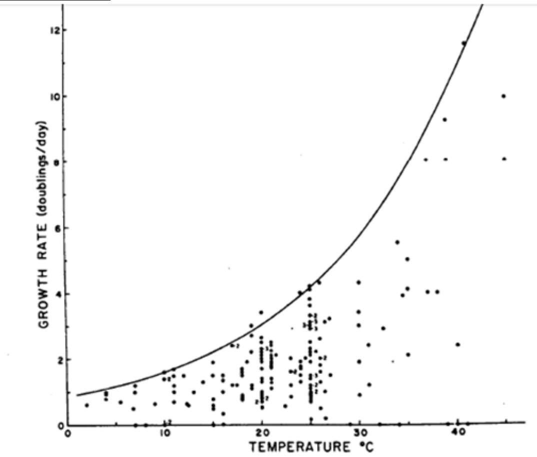
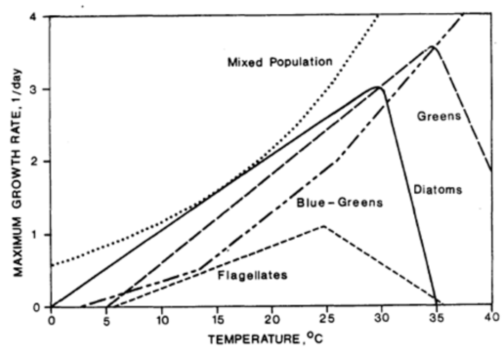
We agree that showing the amount of oxygen necessary to meet 5 mg/L at the bottom could be if interest. However, this is not part of our scope of work for the current phase of the project. This may be a question posed when evaluating management scenarios.</td></tr>
<tr><td>23</td><td>N:P ratios

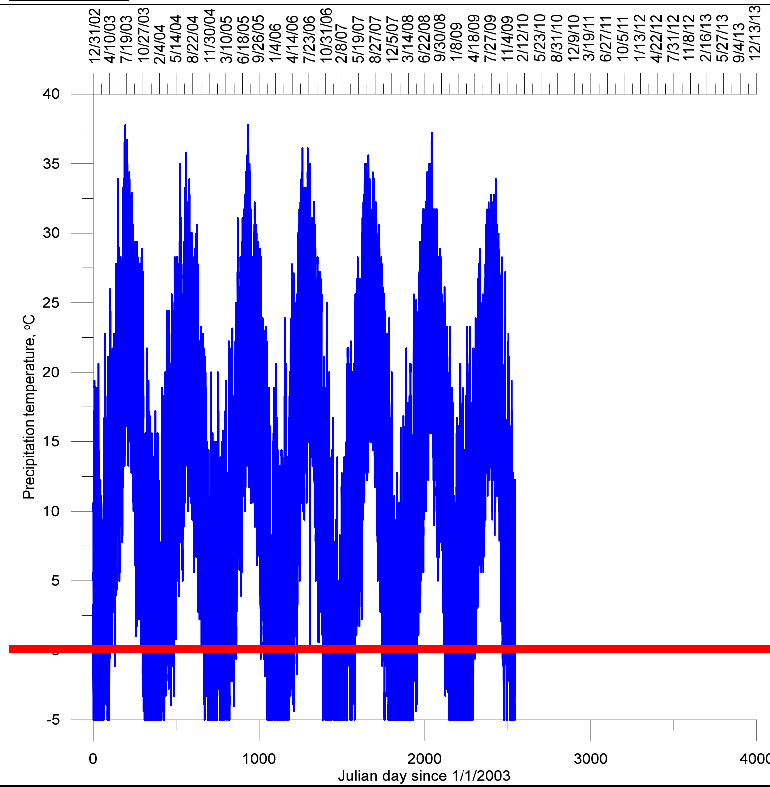
Figure 18 and Table 1</td><td>Inorganic N goes down in 2010-2013 according to Table 1. But in Fig 18 on p. 18 N:P ratios seem to increase between 2010-2013 for Cherry Creek, the main contributor to the reservoir. Perhaps the high increases in Cottonwood Creek in Fig 18 prior to 2010 affected the statistics in Table 1?

Why not also show a TN:TP ratio since many of the organic N and P will</td></tr>
</table>

#	Subject	Comment
		be converted to inorganic N and P?
	Response The table and figure referenced by Dr. Wells are not being interpreted correctly. The table presented volume-weighted average inflow concentrations. These are not directly comparable to the time-series concentrations in the Figure, which do not account for flow rate. The decrease in volume-weighted average inflow concentrations of inorganic nitrogen in both Cottonwood an Cherry Creeks indicate decreased loading of inorganic nitrogen relative to SRP loading. This is in agreement with the discussion in the text. The figure noted shows DIN:SRP ratios displayed over time, compared for the inflowing tributaries. The point of this figure is to show significant differences between the two tributaries and a change in the pattern over time. The same general conclusion would be made if TN:TP ratios were presented. Although limnologists have historically focused on TN:TP ratios to investigate the potential for predicting nutrient limitation, researchers have found that other ratios (such as DIN:SRP and DIN:TP) are superior to TN:TP (Morris and Lewis [1988]; Bergstrom [2010]; Lewis et al. [2011]). This makes sense since a significant proportion of organic nitrogen is unavailable to algae. This is why TN:TP was not presented. While it is true that organic P and organic N will eventually be converted into the inorganic fractions, total nutrients are not as useful for investigating short-term algal responses and the higher fractions of refractory to labile organic matter for these inflows (we believe – see Attachment A in the July 31 Tech Memo), would result in longer lags in the conversion.	
24	Algae mortality rates	The report on p. 36 states that "[i]n general, the role of zooplankton on algal growth is expected to be minimal in Cherry Creek Reservoir due to predation by gizzard shad and young walleye (Boyer et al, 2014a and Lewis et al., 2004). Based on this the small amount of pressure on the phytoplankton was simulated with slightly increased mortality rates in lieu of simulating the highly suppressed zooplankton." Mortality rates used in the model were from 0.05 to 0.15 day^{-1} while the recommended default value was 0.1 day^{-1}. It is unclear that there was any "increased" algae mortality added to the model to account for zooplankton. Non-predatory mortality rates from EPA (1985) were from 0.02 to 0.17 day^{-1}.
	Response The zooplankton settings are constant in the final calibrated model. In tha tmodel algal mortality rates were set to 0.1 for non-nitrogen fixers and 0.16 for nitrogen fixers. This is within the range noted by Dr Wells in the comment of 0.02 to 0.27 (EPA, 1985).	
25	Algae parameters: AHSN, Half saturation for N are set to 0.001 mg/l as N for algal species 1, 2, and 4	EPA (1985) suggests for total phytoplankton this should be in the range of 0.025 mg/l. Cole and Wells (2015) suggest a range of 0.002 to 0.9 with a recommended value of 0.014 mg/l N. This set of half saturation constants is well-outside the range of algae coefficients. It is clear the modeling team is trying to take up more nutrients since the model has a bias in nutrients.
	Response The AHSN in the final calibrated model is 0.003. We recognize that a value of 0.0031 mg/L is low	

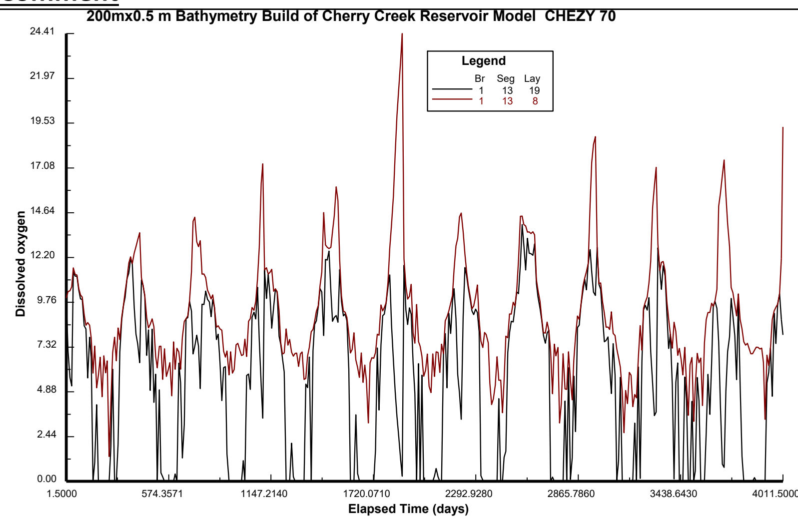
#	Subject	Comment
	compared with much of the literature, though it is in the range suggested. It seems reasonable to believe that a system that tends toward strong nitrogen limitation through much of the growing season, would respond with growth at low levels of nitrogen, corresponding to low AHSN. The value used by Hydros is comparable to the the AHSN settings used in Berger, Wells, Annear (2003) for Timothy Lake for four out of eight of the algal groups in that model. It is unclear why this setting is reasonable for Timothy Lake , which also included nitrogen fixing cyanobacteria, but not for Cherry Creek Reservoir. Further AHSN values as low as 0.001 mg/L are reported in EPA (1985) for several algal types in (Table 6-10, pg 327-328). *Berger, C., Wells, S., and Annear, R. 2003. Technical Memorandum to Foster Wheeler Environmental Corporation Re: Timothy Lake Calibration. January 21.* *EPA (1985). Rates, Constants, and Kinetic Formulations in Surface Water Quality modeling (Second Edition). EPA/600/3-85/040. June 1985.*	
26	Algae parameters: ASAT	The algae light saturation values (ASAT) were very low. This is the optimal light for the algae photosynthesis. Photo-inhibition occurs above this optimal level. They were set to between 50-75 W/m^2. This generally seems low even though there is a hypothesis that the high turbidity and self-shading contributes to an algae population that is sensitive to low-light. EPA(1985) recommends values between 100-170 W/m^2.
	Response: The ASAT values int eh final calibrated model range from 60 to 140. The values used by Hydros seem reasonable given the hypothesis that the algae are adapted to lower light and the range of values in the literature. The values for ASAT are generally above the literature values reported in Table C-62 in the CE-QUAL-W2 v3.71 manual. Also, as noted for AHSN, the lower values used match the range of ASAT settings for five out of eight algal groups in Timothy Lake (Berger, Wells, and Annear [2003]).	
27	Winter algae group 2 maximum growth rate	The winter algae group has a growth rate of 2 day^{-1} at 1°C. This is very high. The maximum recorded values of growth rate at low temperatures seem to be closer to 0.5 day^{-1} as shown in EPA (1985):

#	Subject	Comment
		 Figure 6-2. Envelope curve of algal growth rate versus temperature for data compiled from many studies involving many different species (adapted from Eppley, 1972; Goldman, 1981). and  Figure 6-3. Temperature-growth curves for major algal groups (from Canale and Vogel, 1974).
	<u>Response</u> Significant amounts of algae do grow in winter in this system, including under the ice at very low water temperatures. Observed chlorophyll *a* can be high in winter (e.g., 57 ug/L in January of 2007). While a higher ACHLA is expected, algal biomass can also be high in the winter (e.g. 2.1 mg/L in February of 2009). For the five years of algal biomass data, the model sometimes under-predicts the winter biomass and sometimes it is over-predicted.	
28	Precipitation temperature	The precipitation are temperature was often below zero. This is incorrect and the precipitation temperature should not use the air temperature but the dew point temperature with a lower limit above 0.0. The precipitation temperature is shown below:

<table>
<tr><th>#</th><th>Subject</th><th>Comment</th></tr>
<tr><td></td><td></td><td>
</td></tr>
<tr><td></td><td colspan="2">Response
We disagree with this recommendation. Cutting off precipitation temperature at zero prevents precipitation from falling as snow. Snow temperature can range from near zero to well below zero C. Byers et al (1949) indicate that precipitation temperature relative to air temperature varies depending factors including drop size, travel time, and timing relative to the start of a storm. In some cases precipitation temperature is better described by ambient wet-bulb temperature and in others it better matches air temperature. Without entering into that level of speculation, we recommend keeping the current assumption. If the Authority requests, we can run a sensitivity analysis to see if results would vary with the use of dew point in place of air temperature, without a cutoff at zero. We believe it is unlikely that this change would show an effect on model results or conclusions.

Byers, H.R., Moses, H., and P.J. Harney. 1949. Measurement of Rain Temperature. U.S. Weather Bureau Thunderstorm Project. February 1949, pg 51-55.</td></tr>
<tr><td>29</td><td>Inflow temperature</td><td>It was mentioned that seasonal monthly regressions were used with air temperature and flow rate. Little details were presented in the current reports. This may be an appropriate approach, but we recommend using the equilibrium temperature and flow rate. Showing how well the inflow temperatures matched boundary condition data would help clarify this.</td></tr>
<tr><td></td><td colspan="2">Response
This is a level of detail that is beyond the report outline. This information is available upon request. Such approaches have been used with success on many projects including to estimate tributary inflow temperatures for simulation of hourly river temperatures on the Colorado River, the Fraser River, and the Cache la Poudre River. Further, as a reminder, the model was found to</td></tr>
</table>

#	**Subject**	**Comment**
	not be highly sensitive to this input, with reservoir temperature being largely controlled by meteorological drivers.	
30	Model error statistics for temperature and dissolved oxygen	a. The error statistics for temperature and dissolved oxygen that were presented look reasonable. A look in the Appendix on model vs data comparisons seemed to be worse than the error statistics suggested based on our experience. We may be incorrect, but we recommend re-checking how the profile errors were computed. b. The target for bias (or mean error) in comparisons of field data and model predictions should be close to zero. The actual bias reported for temperature was -0.3°C. Is there any indication as to why that was the case and how that could be adjusted? The evaporation coefficients and/or wind could be responsible for that bias.
	Response 30a. Error statistics have been checked and are correct. 30b. A bias of -0.3°C seems small to us; however, in the final calibrated model, the bias ranged from -0.2°C to 0.1°C, depending on location. The temperature simulation is considered to be robust, given all the error statistics and the comparisons to continuous thermistor data at all depths. We do not tend to calibrate with a primary focus on minimizing error statistics. We could vary the WSC slightly (and consistently over all years) to attempt to adjust this bias, but the effect on other error statistics would likely result in an iterative treatment. At this time, it is not clear that such an effort is worth the cost for what is already a strong temperature simulation.	
31	Dissolved oxygen calibration	In Fig 49 on p. 50, the model under-predicts dissolved oxygen conditions in the surface layer. Even though the consultant claimed that the dissolved oxygen probes were not calibrated properly, there was no proof shown that the dissolved oxygen probes were out-of-calibration. Many models have trouble meeting super-saturation conditions. This is often related to algae biomass and reaeration. The reaeration coefficient used in the control file, w2_con.npt, is Equation 1 for a Lake. We recommend using a different reaeration model and doing sensitivity analyses to see if lowering the reaeration coefficient could raise model predicted dissolved oxygen conditions. As shown in the CE-QUAL-W2 User Manual (Cole and Wells, 2015) in Figure B-25, the chosen reaeration formulation is higher at low wind speeds than most of the other formulations. Sensitivity graphs showing the impact of these on model predictions would be useful. To illustrate how no oxygen transfer at the surface affects dissolved oxygen conditions, note this graph of DO at the dam at the surface and at the bottom:

<table>
<tr><th>#</th><th>Subject</th><th>Comment</th></tr>
<tr><td></td><td></td><td>


This shows that all the high dissolved oxygen periods at the surface occur in the winter under ice cover conditions. In GEI (2013), high winter dissolved oxygen was noted in 2012: “Dissolved oxygen profiles collected in mid-January, during ice-covered conditions, indicated the Reservoir was well oxygenated (7.8 to 16.14 milligrams per liter (mg/L))”. This is also shown in Fig 49 (even though the January 2012 winter DO data does not seem to be part of the observed data set used in Hydro’s report since there is no 16.14 mg/l data point for 1/17/2012 at CCR2) as shown below:

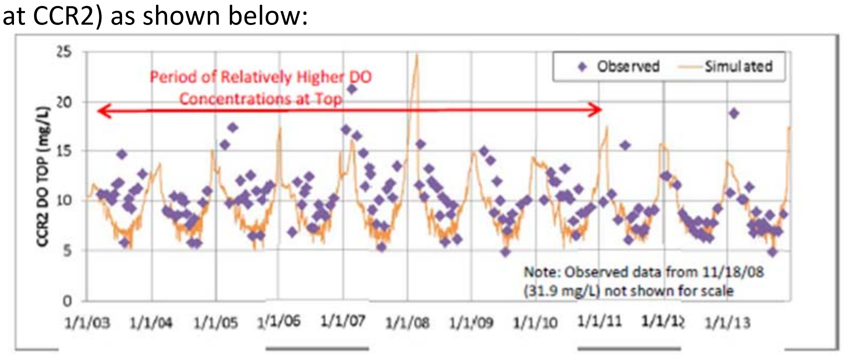
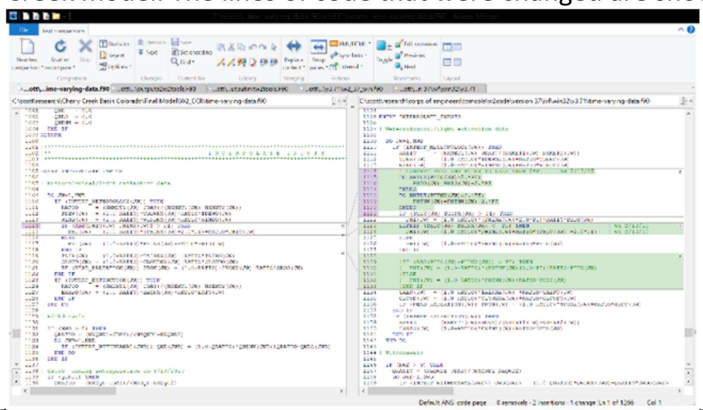
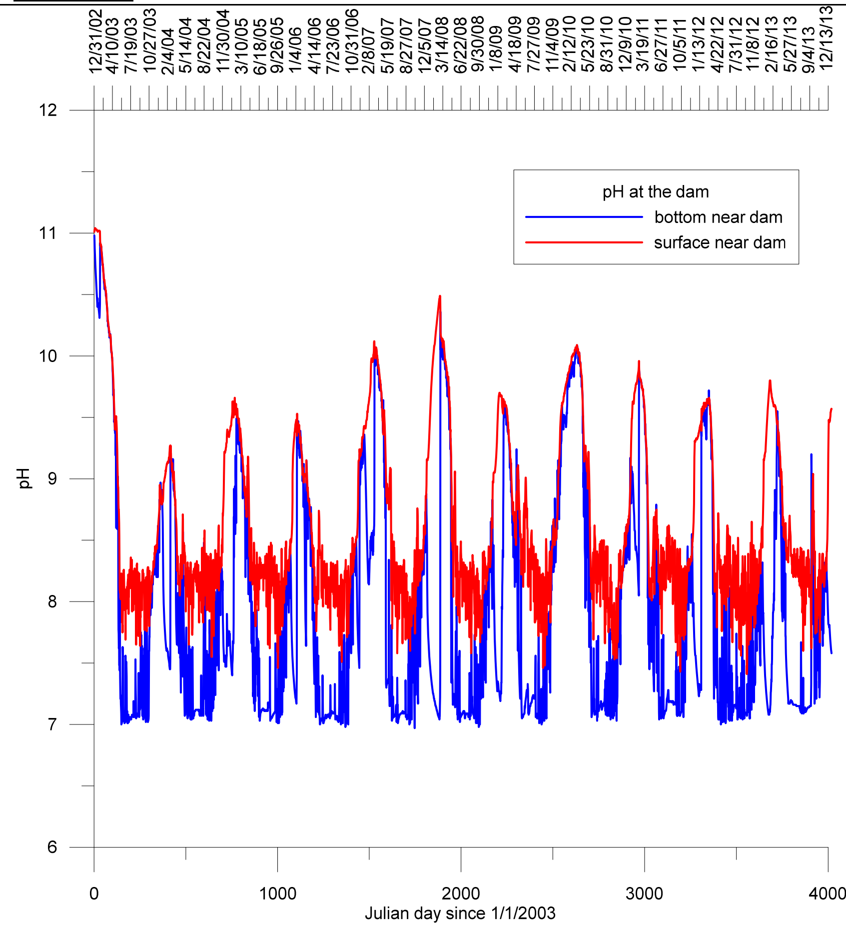


Figure 49. Observed and Simulated Dissolved Oxygen at the Top, CCR2, 2003-2013
</td></tr>
<tr><td></td><td colspan="2">
Response

1. Hydros did not claim that the probes were out of calibration. We proposed a theory and recommended revisiting procedures to check the theory. In that report, Hydros states that this is speculative since we have no evidence beyond surprising temporal patterns, magnitudes, and relative same-day values.
2. We did vary the reaeration coefficient in the calibration process. Lake 1 gave us the best results. We did not repeat that process at the end of the calibration. A sensitivity analysis could be done with the final calibrated model if requested by the Authority. Our experience with this tool and adjusting this parameter indicates that this will not result in an improved match of the DO, so it is not in our recommendations. As the model is updated in the future with additional DO data, the reaeration equation selection will be adjusted, as appropriate, if it improves the fit.
3. We do not dispute that supersaturated DO conditions occur in the reservoir, including
</td></tr>
</table>

#	Subject	Comment
	winter months. The model also simulates supersaturation of DO in the water column. 4. The referenced DO concentration from 1/17/2012 is from a depth of 0 m in the database. Our plots present data from 1 m against simulation results from 1 m. Therefore the value noted is not on our graph.	
32	Maintaining source code for Cherry Creek Reservoir Model	A bug fix was made on 2/13/2015 with regard to interpolation of wind direction. This section of code was not part of the customized Cherry Creek model. The lines of code that were changed are shown below: 
	Response We will update our code to include your recent bug fix to the CE-QUAL-W2 source code. The version of the model Hydros used was the most up-to-date version available at the beginning of the Cherry Creek Model development.	
33	Model set-up for Alkalinity and Total inorganic carbon but not for pH	The model was predicting alkalinity and total inorganic carbon, but was not outputting pH. Even though the consultant says that pH is not being simulated because of lack of good alkalinity data, pH is an important element for evaluating the inorganic C balance in the reservoir and improving model calibration. The model predicted pH is shown below:

#	Subject	Comment

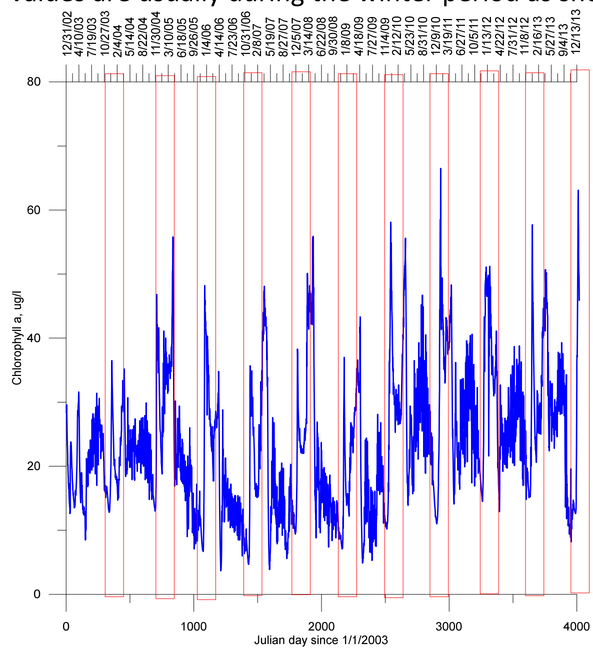


No field data were provided for pH and the modeling team were not focusing on pH, but in any highly eutrophic system understanding pH dynamics is helpful in calibrating and understanding the algae dynamics. As shown above the pH was extremely high in winter periods – because of high algae growth and no oxygen/CO2 transfer across the air-water interface. Summer pH was around 8.2 at the surface and 7.0 at the bottom reflecting bacterial activity. According to GEI (2013), the pH in 2012 surface waters in the summer was in the range of the model predictions, but the winter pH was too high. Also, bottom pH in the model may be somewhat too low, indicating that the model has too much biological activity occurring in the sediments. But a full analysis of the sources/sinks of inorganic C is necessary before conclusions can be reached.

The main point is that it is a useful state variable to ensure that model is properly predicting algae and sediment dynamics, and we highly recommend using it during calibration even if boundary condition data are imperfect.

Response
The Authority can consider whether to add pH to the analysis in the future. As noted, simulating pH was not part of our original scope.

<table>
<tr><th><u>#</u></th><th><u>Subject</u></th><th><u>Comment</u></th></tr>
<tr><td rowspan="2">34</td><td>Algae maximum chlorophyll a in winter</td><td>Algae also exhibits an interesting behavior that the peak chlorophyll a values are usually during the winter period as shown below:



With a reduction in winter algae growth rates at 1°C, this will probably change (see point #27).</td></tr>
<tr><td colspan="2"><u>Response</u>

High winter chlorophyll *a* concentrations may be unusual in other parts of the country but are not unusual for Colorado reservoirs and are observed at Cherry Creek Reservoir. This was discussed at the June 22, 2015 meeting.

As stated in the response to comment 27, significant amounts of algae do grow in winter in this system, including under the ice at very low water temperatures. The evidence for this is high winter chlorophyll *a* (e.g., 57 ug/L in January 2007) <u>and</u> high algal biomass (e.g., 2.1 mg/L in February 2009). For the five years of algal biomass data, the model sometimes under-predicts winter biomass and sometimes it is over-predicted.</td></tr>
<tr><td rowspan="2">35</td><td>Comparison of field data of TP and TN to model predictions</td><td>During the presentation on September 24, field data of total forms of nutrients exist, as well as some focused field data in 2013. Comparing these model predictions to field data would help the model calibration.</td></tr>
<tr><td colspan="2"><u>Response</u>
These comparisons were made as part of the calibration process. Because of the uncertainty in TOC inputs for the full simulation period, there is uncertainty on the organic portion of TN and TP. We considered nitrate, phosphate, and ammonia to be our key calibration targets for nutrients given the focus on algal growth.</td></tr>
</table>

Summary and Final Comments

A summary of major points raised and suggestions for further model changes are shown in Table 2.

Table 2. Overall comments on the model and monitoring recommendations.

#	Topic	Comment
1	Summary of recommended model changes	The following points should be addressed in the calibration: • Choose model parameters within literature values for algae N half saturation (AHSN), winter algae growth rate, BETA, and light extinction coefficients for algae especially since the "calibration was performed by adjusting conceptually-relevant coefficients within reasonable ranges" (Hydros Consulting, 2015) • Fix coding errors for August 2012 fish kill and adjust C, N, P values and provide justification for changes in burial rate • Re-evaluate wind speed and direction data • Develop a new temperature file for precipitation • Update customized code using updated fixes in the release version • Use field data of TP and TN and other more focused data from 2013 to compare with model predictions • Simulate zooplankton for the entire period of simulation (they are already simulated just forced ON and OFF for certain time periods) • Compute pH for the entire period of simulation (pH is derived from Alkalinity, temperature, and total inorganic C which are already simulated) and use this information to inform the model on algae productivity and biological activity • Have model predict evaporation and compare to evaporation data rather than specify evaporation externally
2	Areas for further documentation and analysis	The report should document • Model prediction of ice cover and the impacts of ice cover on nutrients in the following year, • Organic matter loading to the reservoir • Determination of inflow seeds of zooplankton (0.0) and algae (0.02 mg/l) • Differences in TIN:SRP and TN:TP ratios • Cause in the model of low light extinction • Better algae characterization o The temperature ranges for the mixed groups of algae included in the mix of algae were probably broader than the narrow ranges specified in the model. We realize this is an attempt to provide some context to the algae in Cherry Creek and points to the need for

<table>
<tr><th>#</th><th>Topic</th><th>Comment</th></tr>
<tr><td></td><td></td><td>better algae characterization. This is not an easy topic, but the current temperature ranges force that group of algae to be dominant during certain parts of the year.</td></tr>
<tr><td rowspan="2">3</td><td>Suggestions for model improvement included: (1) sediment burial rates changing over time, (2) varying stoichiometry of algae, and (3) allowing N fixers to obtain water column N when available</td><td>All of these changes could be added to the Cherry Creek model, but they add to the complexity of the model. There is often the balance between adding more ‘knobs’ to turn to adjust a calibration versus having the knowledge base (from Cherry Creek Reservoir) to make those changes. We try to add complexity when it has been demonstrated that that complexity is an important process in the water body under study. For example, it is not clear what the mechanism for changing burial rates over time would be or how that could be predicted other than through a modeler turning ON or OFF sediment impacts just to match data. Changes in burial rate though could be linked to increasing inorganic suspended solids loading.</td></tr>
<tr><td colspan="2"><u>Response</u>
We think there is a mixed message here. Recommendations by Wells include simulating sediment diagenesis, adding pH and inorganic carbon, making year-by-year adjustments to wind sheltering, and adjusting to correct a -0.3°C bias in temperature. These recommendations involve adding and turning many additional knobs. Our recommendations have been focused on areas where we feel the current model does not capture important dynamics in the Cherry Creek Reservoir. If there are other adjustments outside of the recommended recoding that can capture these mechanisms, we are very interested in discussing them. We haven’t seen such recommendations in these comments.</td></tr>
<tr><td>4</td><td>Monitoring recommendations</td><td><u>Continuous water quality monitoring</u>
One suggestion was to provide continuous dissolved oxygen monitoring at 1 m below surface and 0.5 m above bottom. This may be difficult because of the sediment fluff at bottom. Continuous record at the dam discharge and intensive 1-week continuous survey in the reservoir would be very useful. Continuous outflow DO, pH, and temperature would be very useful.

Characterization of organic matter coming into the reservoir is necessary to determine the labile:refractory ratio. As shown in Table 3 (#6), the percentage of labile to refractory organic matter is critical to understanding the oxygen balance in the reservoir.

<u>Meteorological data</u>
Need to measure on-site wind on the lake during every sampling trip to correlate to a continuous wind gage.

<u>Inflow algae</u>
While the suggestion of monitoring algae in the inflow would be useful, the characterization of organic loading from the main tributaries is more important.</td></tr>
</table>

#	Topic	Comment
	Response We agree is would be good to characterize organic matter loading from the tributaries. We also agree it would be good to measure on-site wind during sampling trips. Regarding a DO probe: DO in the outfall is a more indirect measure of in-reservoir DO at the bottom, and represents a varying mix of DO from the water column. We think it would be most valuable to have the in-reservoir bottom DO, if possible.	