PLAN OF STUDY
OXYGEN DYNAMICS ASSESSMENT
LOWER MINNESOTA RIVER

Prepared by:

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1.0 INTRODUCTION

Metropolitan Council Environmental Services (MCES) plans to develop water-quality models of the lower 40 miles of the Minnesota River to study current and future impacts of the existing dischargers. At issue are dissolved oxygen concentrations under summer low flow conditions and the river's ability to assimilate waste loads. The river reach of interest extends from above the wastewater treatment plant near Jordan (river mile 36) to the mouth of the Minnesota (Figure 1). Key to MCES's modeling effort is the acquisition of specific field data on oxygen dynamics in the study reach under low flow conditions. Accordingly, this plan of study will serve as a logistical, technical, and QA/QC guide to project personnel during the acquisition of such data. While serving as a guide, technical approaches outlined in this document may be modified, based upon best professional judgement of the lead scientist, during the on-site accomplishment of field activities as is often necessary during the course of scientific assessments. The scientific rationale and methods used to develop this document have been previously presented in the scope of work for "Basic Services" portion of the contract between MCES and HydrO_2, Inc.

2.0 OBJECTIVE

2.1 The primary objective of this survey is to collect a representative set of diffusion rates, reaeration rate coefficients, time-of-travel, sediment oxygen demand rates, water column production and respiration rates, total community production and respiration, and community substrate oxygen demand rates for the lower Minnesota River at low flow conditions.

3.0 SCOPE

3.1 To collect the required set of information, several activities must be conducted simultaneously within the defined reach of the Minnesota River. Such activities are interrelated and must be conducted during a period when river and discharge conditions are relatively constant. MCES has indicated that river flows below 1500 will be the target conditions for assessment of oxygen dynamics. The initial study will include all parameters specified in Section 2.1 above and will be initiated at flows selected by MCES below the 1500-cfs limit. A second study will be conducted at the discretion of MCES at flows contrasting to the initial study, and will include the parameters of diffusion via the floating dome method, total community metabolism, water column metabolism, and community substrate oxygen demand. The USGS gage at Jordan, Minnesota River (Station # 05330000) will be used as the reference flow station. Historical information indicates that the seasonality of these flows generally occurs in the period from late July to early September. Acquisition of this data will be a joint effort including HydrO_2, Inc. and personnel from MCES and MPCA.

The following survey components will be assessed via a survey module approach:

Module 1 - Diffusion/Reaeration (Ka) Rate Coefficients

Module 2 - Sediment Oxygen Demand (SOD) Rates

Module 3 - Water Column Production & Respiration (WCPR) Rates

Module 4 - Total Community Production & Respiration (TCPR) and Community Substrate Oxygen Demand (CSOD) Rates

Tasks and procedures associated with the above survey components are defined in the following activity specific modules. The modules will be completed in three phases of activity: study preparation, field survey and report writing.

3.2 Station Locations

Except for reaeration/diffusion for which data will be collected longitudinally through nearly the entire study reach, six stations have tentatively been selected for assessment of TCPR, CSOD, SOD, WCPR. The primary rationale guiding selection of station location was the strategy of assessment of reaches according to the influence of various discharges and their potential effect on water quality and hydrology, particularly their influence on the oxygen dynamics components listed above. Influential factors include the Blue Lake WWTP, Black Dog Power Generating Facility, Seneca WWTP, Minneapolis/St. Paul International Airport, and changes in river morphology associated with navigation channel in the lower reach.

Additionally, SOD stations should be representative of the dominant substrates within the reach. Accordingly, sediment bed maps developed through USGS and MCES efforts for the lower 26 miles of the river were provided by MCES to HydrO2 and used to determine dominant substrate types within potential station locations, thereby enhancing the confidence in the representativeness of SOD sampling sites. Based on these maps, the Minnesota River bed is dominated at summer low flows by two substrate mixes with sand/silt being the most dominant, followed by sand/gravel. Chamber placement for SOD measurement will target these two substrate types. Generally, sand/silt appears as the dominant substrate at 4 of the 5 station locations within the segment of the river that was mapped. Between river miles 7 and 11, mapping indicates dominance by sand/gravel. SOD rates for this component will be captured in measurements made at the tentative station RM 10.8 or thereabout. Since the sediment mapping indicates an increasing trend toward dominance by sand/silt with progression upstream, the most upstream station will, likewise, be positioned over sand/silt substrate unless conditions observed at the time override such logic. If at all possible within the constraints of equipment deployment and boat positioning, if substrate variability between sand/silt and sand/gravel can be addressed more discretely while on specific stations, attempts will be made to do so. Diver observation of substrate type associated with each individual chamber will be recorded and a two-inch acrylic core sample of representative bottom sediments will be extracted and photographed at each station.

Based on the above rational, anticipated station locations for TCPR, SOD, CSOD and WCPR are presented below in Table 1.

TABLE 1

STATION LOCATION (River Mile)	PLACEMENT FACTORS
RM 1.2	Downstream boundary conditions and below Seneca WWTP and airport outfalls
RM 6.8	Upstream of Seneca WWTP; downstream of Black Dog; within deeper navigation channel
RM 10.8	Downstream of Blue Lake WWTP; Upstream of Black Dog; within deeper navigation channel
RM 14.6	Downstream of Blue Lake WWTP; upstream limits of navigation channel
RM 25	Upstream of Blue Lake WWTP; beyond maintained channel
RM 37 *	Injections site; upstream of Carver Rapids; upstream boundary conditions

* Location may shift based on boat access and Carver Rapids.

4.0 STUDY TASKS

4.1 PREPARATION PHASE

In anticipation of the field survey, several activities must be conducted not withstanding this plan of study. These activities include preparation of calibration solutions for both the fluorometers and dissolved oxygen meters. Supplies and equipment must be acquired and/or serviced. Pumps and diffusion domes used in both reaeration and sediment oxygen demand measurements must be tested for seal integrity and output rates. Aeration plates must be tested for performance and delivery. All remaining equipment must be cleaned, staged and packed for transport.

4.2 FIELD SURVEY PHASE

As previously stated, the anticipated window of opportunity is mid to late summer when river flows are expected to be below 1500 cfs and water temperatures near average maximum. Accordingly, specific study dates have not been established. Observation by MCES of river discharge conditions monitored by the USGS gaging station at Jordan will occur through the summer season. As river discharge declines toward the targeted flow, mobilization will intensify in anticipation of river conditions reaching their optimum for the study.

With mobilization completed and river discharge conditions optimal, the time line in Table 2 indicates the sequence of events anticipated for accomplishment of the field activities once $HydrO_2$ personnel arrive at the project site. Expected tasks for each cooperating agency are identified in Table 3 subsequent to the field activity schedule. Specific station locations will be designated according to river mile and GPS coordinates at the time of study. Maps guiding the study are “Data Sources and Major Discharges” (Figure 1; Thomas Winterstein, USGS) and “Canoe and Boating Guide” (Minnesota Department of Natural Resources), which will be provided to field personnel at initiation of the study.

4.3 REPORT PREPARATION PHASE

Upon completion of the field activities, samples for gas analysis (argon/krypton) will be transported by $HydrO_2$ to Athens, Georgia, and delivered to the University of Georgia, Center for Applied Isotope Studies (CAIS). Anticipated time for analytical services to be completed is four to six weeks. Following receipt of the data from CAIS, $HydrO_2$ will initiate data analysis for development of a draft report to be furnished to MCES consistent with the timetable specified in the contract. The draft report will include the following:

1. Integrated krypton-based reaeration rate coefficients for reach 1 through reach 3
2. Comparison of reaeration rate coefficients generated using the krypton technique versus those measured using the diffusion dome technique for reaches 1 and 3
3. Integrated diffusion dome-based reaeration rate coefficients for all other reaches measured
4. Tabular presentation of replicate and mean SOD rates at each of the six sediment oxygen demand stations
5. Tabular presentation of all water column production and respiration measurements
6. Tabular presentation of diurnal dissolved oxygen data and total community production and respiration
7. Tabular presentation of the community based substrate oxygen demand data

Following review, discussion and concurrence on the draft report between $HydrO_2$ and MCES, a final report will be prepared by $HydrO_2$ and forwarded to MCES within time specified in the contract.

TABLE 2

Team	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7	Day 8
1 Murphy Hicks Larson *	Recon-naissance Survey	SOD & WCPR at RM 37.0, Krypton & dye injection	SOD & WCPR at RM 25.0	SOD & WCPR at RM 14.6	SOD & WCPR at RM 10.8	SOD & WCPR at RM 6.8	SOD at RM 1.2	Demobilize
2 Cavinder Koenig	Recon-naissance Survey	Ka mixing-pt sampling, Diffusion float to end of reach 1, Ka sampling end of reach 1	Ka sampling end of reach 2, Diffusion float through reach 3, Ka sampling end reach 3	Diffusion float for reach 4	Diffusion float for reach 5	Diffusion float for reach 6	WCPR at RM 1.2	Demobilize
3 Rott plus MPCA staff	Recon-naissance Survey	Deploy sondes for TCPR at 3 upstream stations		Retrieve sondes, check calibration, download data, recalibrate and redeploy at 3 downstream stations	Optional sonde redeployment day		Retrieve sondes, Check end calibration and download data	Demobilize
4 MCES Courier		Pick up & transport chlorophyll samples to lab; other tasks as assigned	Pick up & transport chlorophyll samples to lab; other tasks as assigned	Pick up & transport chlorophyll samples to lab; other tasks as assigned	Pick up & transport chlorophyll samples to lab; other tasks as assigned	Pick up & transport chlorophyll samples to lab; other tasks as assigned	Pick up & transport chlorophyll samples to lab; other tasks as assigned	

* After Day 2 injection, Larson may be substituted with other MCES staff. An additional fourth person may be aboard the SOD boat for observation and assistance if space is available.

TABLE 3

Organization	Study Responsibilities
HydrO2, Inc.	Design Study
	Lead and/or conduct Ka/Diffusion, WCPR, SOD, CSOD, and TCPR
	Provide field equipment for SOD, Ka/Diffusion, and WCPR
	Supply two boats; 24' pontoon for SOD, and 16' shallow draft jon boat for Ka/diffusion
	Collect water samples for chlorophyll analysis related to WCPR
	Collect and transport samples for krypton/argon analyses to Univ. of GA
	Analyze, interpret, and report all oxygen dynamics data to MCES
MCES	Reconnaissance participation. Provide 1 person to assist with gas/dye injection for reaeration and subsequent SOD work at all stations each day; Person assisting can be rotated at 2-3 day interval.
	Provide courier for chlorophyll samples, SCUBA tank re-fill, and other courier assistance as needed
	Provide containers (approx. 30) for chlorophyll samples; filter water samples and conduct chlorophyll analysis
	Provide jon boat throughout study as needed
MPCA	Reconnaissance participation. Provide 6 sondes (minimum) and associated buoys, anchors, and boat for deployment
	Deploy sondes for acquisition (at 30-minute logging intervals) of DO, DO sat, temp, pH, and conductivity
	Calibrate all sondes before and during study; check calibration after completion of study; download data into comma-delimited files and provide to HydrO2

5.0 MODULE 1: REAERATION RATE COEFFICIENTS

5.10 Objective

To provide field data on the rate of reaeration for an approximate 36-mile reach of the Lower Minnesota River.

5.20 Anticipated Activities

5.21 The non-radioactive krypton technique (Unpublished, Koenig and Cavinder) involves the use of a gaseous tracer to make a direct and independent evaluation of stream reaeration capacity. This technique constitutes a direct measurement of gas exchange between the water column and the atmosphere. Specifically, this method uses a steady-state injection of non-radioactive krypton gas in concert with Rhodamine WT dye. HydrO2's approach to this technique is an advancement of the radioactive Krypton 85 technique pioneered by Tsivoglou (1967) in that

1. The use of nonradioactive krypton eliminates the health and environmental concerns associated with Krypton 85, and

2. It is injected, along with the dye, in a continuous steady-state mode-enhancing vertical and cross-sectional mixing and creating a sustained plateau concentration for a considerable period, which enhances replicate sampling.

The passage of the gas and dye cloud is successively monitored and sampled as it moves downstream in the Minnesota River through the study area. The desorption of krypton gas is correlated to an absorption of oxygen for the purpose of determining a reaeration rate coefficient for the subject reach under study. Three reaches in the upper portion of the forty-mile study reach will be evaluated.

The non-radioactive krypton technique will be used to corroborate a second field procedure referred to as the diffusion dome technique. This technique pioneered by Copeland, Duffer and Hall, has been further refined by personnel with HydrO2 through adjustments to dome volume, temperature control management and control, and conducting measurements under conditions within ambient oxygen saturation deficits occurring at the time of assessment. The field crews will use the diffusion dome to measure reaeration rate coefficients for approximately 36 miles of the lower Minnesota River. The reaeration rate coefficients measured on the upper portion of the Minnesota River using the krypton technique will serve to validate the reaeration rate coefficients developed using the diffusion domes. To accomplish this an approximate 12.4-mile long non-radioactive krypton reach will be segmented into three sub-reaches. The first and third reaches will each span a short distance, while the second reach will span a longer distance. Diffusion dome floats will be made simultaneous with the passage of the dye and krypton gas through the short first and third reaches. This will allow for the comparison in reaeration rate coefficients for the two techniques. The remaining approximate 28 miles will be measured using the diffusion dome technique.

5.22 Collect samples for non-radioactive krypton and argon analyses from pre-selected location (Figure 1) in phase with the passage of the dye cloud plateau.

5.23 Expand monitoring of the dye cloud beyond the flow-through period to include the entire depiction of the dye curve for the purpose of determining time of travel. Monitoring will involve collecting aliquots of river water with automated sampling equipment and analyzed for dye concentration with a pour-through fluorometer or monitoring through the use of rhodamine probes affixed to multi parameter water quality instruments.

5.24 For all gas samples collected as a part of this module (1) prepare and process samples according to $HydrO_2$ QA/QC and (2) transport samples to the Center for Applied Isotope Studies at the University of Georgia for krypton/argon ratio analysis.

5.30 Schedule for Activities

5.31 The survey is set to initiate with a gas and dye release starting on field Day 2 at approximately 1200 hours. The activities of this module will center around monitoring the Rhodamine WT dye cloud as it progresses downstream. Reaches of the stream to be monitored are identified by longitudinal mile points provided by the MCES. All field activities will be conducted by boat at river stations. An injection team will be located near RM 37. A team member will be positioned in a boat to monitor the constant rate injection of Rhodamine WT dye and noble gas krypton. An additional crew will be used to monitor and sample for Rhodamine WT dye and krypton/argon gas at subsequent downstream stations and to float the river simultaneous to the passage of the dye and krypton gas through the two short sub-reaches. Monitoring reaches and specific sampling locations with the projected dye passage plateau times are provided (Figure 1) as a guide to field activities.

5.40 Comparative Reaeration Measurements

5.41 Three reaches will be monitored using Rhodamine WT dye and the non-radioactive krypton gas spanning the uppermost 12.4 miles. Tracer injection will be made near river mile 37.0. A constant rate injection of both gas and dye will be made over a period of approximately 12 hours. Downstream monitoring of the tracer release will be conducted near river mile 36, upstream of Carver Rapids. This location will provide for an approximate mixing reach of 1.0 mile. The tracer release will commence as close as possible to 1200 hours. Reaches were segmented to represent the best practical monitoring sites. Monitoring will continue in step-wise fashion downstream. Passage of the dye will be monitored using a flow-through fluorometer system. The krypton monitoring crew will first determine if the dye is mixed throughout the cross section. Initial sampling for argon and krypton gas will start upon verification of a complete dye mix and the establishment of a constant dye plateau concentration. A set of eight replicate samples will be collected using specialized sampling gear to prevent aeration of the sample. The monitoring crew will retire for the day upon completion of sampling for the first reach. They will return in the morning moving downstream, well ahead, of the dye plateau. They will move upstream by boat until they reach the dye and gas plateau. Initiation of sampling will complete this longer second reach. At this point the monitoring crew will initiate the diffusion float for the third sub-reach. This will finish the last comparative reach between diffusion and gaseous tracer techniques. From this point downstream all reaeration rate coefficients will be measured using the diffusion dome.

5.50 QA/QC Requirements

5.51 All standard HydrO_2 QA/QC requirements should be followed to assure consistency in field activities. Several requirements deserve special mention:

5.52 All samples will be returned to the UGA, CAIS laboratory for analyses;

5.53 Chain-of custody for each sample should be carefully documented;

5.54 All field measurements should be fully documented in bound field books and should strictly conform to HydrO_2's standard format;

5.55 All instruments should be properly calibrated and verified at all times during field measurement activities. All calibration activities should be fully documented in the field log books.

6.0 MODULE 2: SEDIMENT OXYGEN DEMAND RATES

6.1 Objective

To provide field measurements of sediment oxygen demand (SOD) rates for spatially representative locations along the Minnesota River.

6.2 Anticipated Module Activities

Sediment oxygen demand (SOD) rates will be measured using the *in situ* chamber method (Murphy & Hicks, 1985). This method involves the diver deployment of opaque chambers over bottom sediments for time periods during which the rate of oxygen consumption is continuously monitored with calibrated and stirred dissolved oxygen probes positioned in each chamber. Three replicate sediment contact chambers 64 liters in volume, incorporating 0.27 m^2 of bottom sediment are effectively sealed to bottom sediments, with the enclosed water volume mixed in an annular flow pattern via a pump and diffuser arrangement to simulate ambient over-bottom mixing. Data is manually logged, typically at 15-minute intervals. Regression analysis of acquired data points yields the oxygen decay rate within each chamber that must be corrected for the respiration rate associated with the 64 liters of water within each chamber to arrive at the effective sediment oxygen demand. The oxygen respiration rate attributable to this water volume is accounted for by concurrent deployment of a fourth chamber identical in dimensions to the sediment chambers but totally enclosed with a chamber bottom, and purged and filled with bottom water. The water column respiration rate acquired with this “blank” chamber is subtracted from each sediment contact chamber rate to arrive at the SOD rate. Continuous on-station examination of data from each chamber allows the scientist to identify potential problems and conduct corrective actions during the course of the deployment, thus enhancing confidence in the effectiveness of the measurements before departing the station.

Results of sediment mapping activities conducted by USGS under low flow conditions in Fall 2003 indicated that, at low flows, the majority of the study reach is dominated by a mix of sand-silt, excepting the river segment generally between River Miles 7-11 where a sand-gravel mix appears dominant. Placement of SOD chambers at the locations presented in Table 1 are expected to correspond to the longitudinal sediment distribution profile developed by USGS with five of the six SOD stations being within reaches dominated by sand-silt, while deployment near RM 10.8 should encounter a sand-gravel mix. Since the sand-gravel mix is, however, a considerable secondary component of the river bed, if local on-station substrate variability presents a sand-gravel mix in conjunction with sand-silt, on-station chamber deployment will attempt to measure rates over variable substrate mixes. Visual records of substrate type will be made along with extraction and photographing of a 2-inch clear acrylic core of representative substrate at each station.

6.3 Schedule for Module Activities

SOD monitoring along the river will be initiated at river mile 37.0. This is the site of the reaeration tracer injection. It will begin on field day 2 of the survey. SOD locations are based upon pre-survey discussions with staff of MCES. Six SOD stations will be longitudinally positioned through the study reach, tentatively near RM 37.0, RM 25.0, RM 14.6 RM 10.8, RM 6.8, and RM 1.2, respectively. GPS coordinates of specific station locations will be obtained during the reconnaissance and subsequent fieldwork. At each station, a total of three replicate SOD chambers will be deployed for assessment of SOD rates. The three-chamber array will be accompanied by fourth chamber equipped for determining a water column respiration rate.

6.40 Sediment Oxygen Demand Monitoring Requirements

6.41 The following procedures will be employed for conducting field measurements of sediment oxygen demand using the previously described equipment.

6.42 Confirm preliminary information about the study area to determine general station locations. Conduct on-site observation of stream and sediment physical conditions to guide decisions regarding location of chamber deployment.

6.43 Calibrate dissolved oxygen meters and other associated monitoring gear. Maintain record of calibration.

6.44 Measure vertical profiles of dissolved oxygen and temperature to assist in evaluation of oxygen resources available for the measurements.

6.45 Check operational status of the equipment.

6.46 Deploy chambers and determine effective chamber to substrate seal.

6.47 Install monitoring probes and engage circulation pump.

6.48 Deploy ambient probe for monitoring of ambient dissolved oxygen.

6.49 Record initial monitoring data and continue data recording at selected time intervals.

6.50 Record monitoring data at selected time intervals.

6.51 Continue experiment for approximately 2-3 hours, or longer if needed, to obtained a satisfactory rate of change.

6.52 Remove monitoring probes from dome and check their calibration. Record calibration check. Check operation of circulation pump just prior to termination of experiment.

6.60 QA/QC Requirements

6.61 Sampling protocol will follow $HydrO_2$ Standard Operating Procedure (SOP) manual.

7.0 MODULE 3: Water Column Production and Respiration Rates

7.20 Objective

A. Determine water column GPP, NPP and R rates (Oxygen Method) at six stations (Table 1) through the deployment of light and dark bottles at selected depths within the water column.

B. Measure visible light attenuation in the water column to determine the depths for light and dark bottle incubation as well as chlorophyll a sampling.

C. Collect independent (non-composited) samples at the targeted incident light transmission levels, equivalent to bottle deployment depths, for chlorophyll a analyses.

7.21 Anticipated Module Activities

7.22 Deploy pyrheliometer prior to sunrise of the first field day.

7.23 Determine exact deployment location in the field to ensure proper placement of the meter away from obstructions.

7.24 Select deployment depths at stations based upon light profiles determined by marine photometer immediately prior to deployment with a focus on integration of the euphotic zone.

7.25 Collect light and dark bottle samples using a submersible pump.

7.26 Measure initial dissolved oxygen concentrations at all incubation depths using the azide-modified Winkler

7.27 Incubate bottles by suspending on floats at the determined depths for an approximate 4 hour period.

7.28 Record retrieval time for the incubated bottles.

7.29 Measure and record final incubated dissolved oxygen concentrations for all light and dark bottles.

7.30 Schedule for Module Activities

7.31 Deployment of light and dark bottles will occur during the midday periods on successive field days 2 thru 7 at RM 37.0, RM 25.0, RM 14.6 RM 10.8, RM 6.8, and RM 1.2, respectively.

7.40 Instrument Calibration/Maintenance

7.41 Check zero line on pyrheliometer during darkness. Check clock for accuracy.

7.42 Zero adjust the marine photometer according to manufacturers specifications. Synchronize deck and sea cells or record variation.

7.50 QA/QC Requirements

7.51 Sampling will be guided by Standard Methods (20th ed) and HydrO_2 Standard Operating Procedure (SOP) manual

8.0 MODULE 4: Total Community Oxygen Metabolism (GPP & R) and Community Substrate Oxygen Demand Rates (CSOD)

8.10 Objective

8.11 Provide field determinations of Total Community Oxygen Metabolism (Gross Primary Production and Respiration) Community Substrate Oxygen Demand rates for the Minnesota River monitoring stations identified in Figure 1.

8.20 Anticipated Module Activities

8.21 Total community oxygen metabolism represents the sum total Gross Primary Production and Respiration for the aquatic community. These metabolic rates are determined using the Diel Curve Method (Odum & Hoskins, 1957 and 1958), with modification by HydrO2 involving correction for atmospheric diffusion using direct measurements of reaeration/diffusion rather than the subjective calculation of diffusion suggested by the pioneers of the method. Use of diffusion rates resulting from concurrent *in situ* integrated measurements of reaeration enhances the accuracy of the dissolved oxygen rate of change calculations, resulting in greater confidence in the quantitation of total community Gross Primary Production and Respiration. Using community respiration rates in conjunction with water column respiration rates, obtained via the Diel Curve Method and Light and Dark Bottle Method, respectively, community substrate oxygen demand (CSOD) rates are computed.

MPCA will deploy two sondes at each selected station. Initial deployment will be at the three upstream stations, followed by sonde retrieval, re-calibration, and redeployment at the three downstream stations. Deployment depths will be based upon light attenuation profiles obtained during the Day 1 reconnaissance.

8.22 Compute the rate of change of oxygen curves for each total station for determining total community Gross Primary Production (GPP) and Respiration according to Odum & Hoskins (1957-1958).

8.23 Correct the rate of dissolved oxygen change curves at each station for the respective diffusion rate based on results of HydrO_2's reaeration and diffusion dome measurements.

8.24 Subtract the respective water column respiration rate, acquired from the Light and Dark Bottle measurements, from the corrected rate of change curve for each station.

8.25 Adjust the resultant community substrate oxygen demand rate for depth.

8.30 Schedule for Module Activities

8.31 MPCA will make the necessary diurnal dissolved oxygen measurements at Minnesota River stations RM 37.0, RM 25.0, RM 14.6, RM 10.8, RM 6.8, and RM 1.2, respectively.

8.32 HydrO_2 will make the necessary water column respiration measurements during Module 3 activities.

8.33 HydrO_2 will make the necessary diffusion rate measurements during Module 1 activities.

8.40 QA/QC Requirements

8.41 Sampling protocol will follow HydrO_2 Standard Operating Procedure (SOP) manual.

REFERENCES

APHA (American Public Health Association), 1999. Standard Methods for the Examination of Water and Wastewater, 20th edition, Part 10200.J.2.

Copeland, B.J., and Duffer, W.R., “Use of a Clear Plastic Dome to Measure Gaseous Diffusion Rates in Natural Waters”, Limnology and Oceanography, Vol. 9, 1963. pp 494-499.

Hall, C.A.S. 1970. “Migration and Metabolism in a Stream”, PhD dissertation. University of North Carolina at Chapel Hill, North Carolina.

Murphy, P.J. and D.B. Hicks, 1986. In-situ method for measuring sediment oxygen demand, *in* Hatcher, K.J., ed., Sediment oxygen demand—Processes, modeling, and measurement. University of Georgia, Institute of Natural Resources, Athens, Georgia, p. 307-322.

Tsivoglou, E.C., “Tracer Measurements of Stream Reaeration”, Federal Water Pollution Control Administration, U.S. Department of the Interior, Washington, D.C. June 1967.

Odum, H.T. and C.M. Hoskins, 1958. Comparative Studies on the Metabolism of Marine Waters. Publ. Inst. of Marine Science, University of Texas, 4:115.

Appendix A
Contacts And Other Logistics

HYDRO2

Del Hicks	706-207-2148 (cell phone)
Mark Koenig	706-247-2139 (cell phone)
Phil Murphy	706-248-1784 (cell phone)
Tom Cavinder	706-296-7823 (cell phone)

VHF Radio Hailing Channel 16 Working channel 82

Lodging for all HydrO2 personnel: (To be determined)

MCES

Cathy Larson	651-602-1275 (or telework 507-645-0256)
Scott Schellhaas	651-602-8341

MPCA

Gary Rott 651-296-9260

Watergate Marina (651) 695-3780. (Their summer operating hours are 7:00 A.M. to 8:00 P.M. but fuel dock hours can be extended upon request)

U.S. Coast Guard Local office (651) 290-3991, Chief McDermid.

U.S. Coast Guard Upper Mississippi River (319) 524-7511, notices of mariners. They want at least seven days notice about our instrument buoys.

River Services Inc. They are the local tow boat company (651)292-9293.

Hennepin County Water Patrol Contact Lt. Jeff Storm (952) 471-1301 about our instrument buoys so that they can notify their officers.

U.S. ACE Dan Krumholz of the Channel and Harbors work group in Fountain City, Wisconsin (608) 687-3112. They handle dredging in the navigational reach of the Minnesota River. They should be told about the buoys so that they are will know not to disturb them. An ACE permit is not needed, since the buoys are only temporary.

Boat Ramps

- Watergate Marina
- Near Highway 77 Bridge (right bank)
- Near Highway 35W (left bank)
- Huber City Park @ Shakopee (right bank)
- Near Hwy 41 @ Chaska (left bank)
- Near Hwy 45 @ Jordan (right bank)

Note: All bank location are looking downstream based on Minnesota River Canoe and Boating guide

Figure 1.

Data Sources and Major Point Discharges in the Lower Minnesota River
(Thomas Winterstein, US Geological Survey)