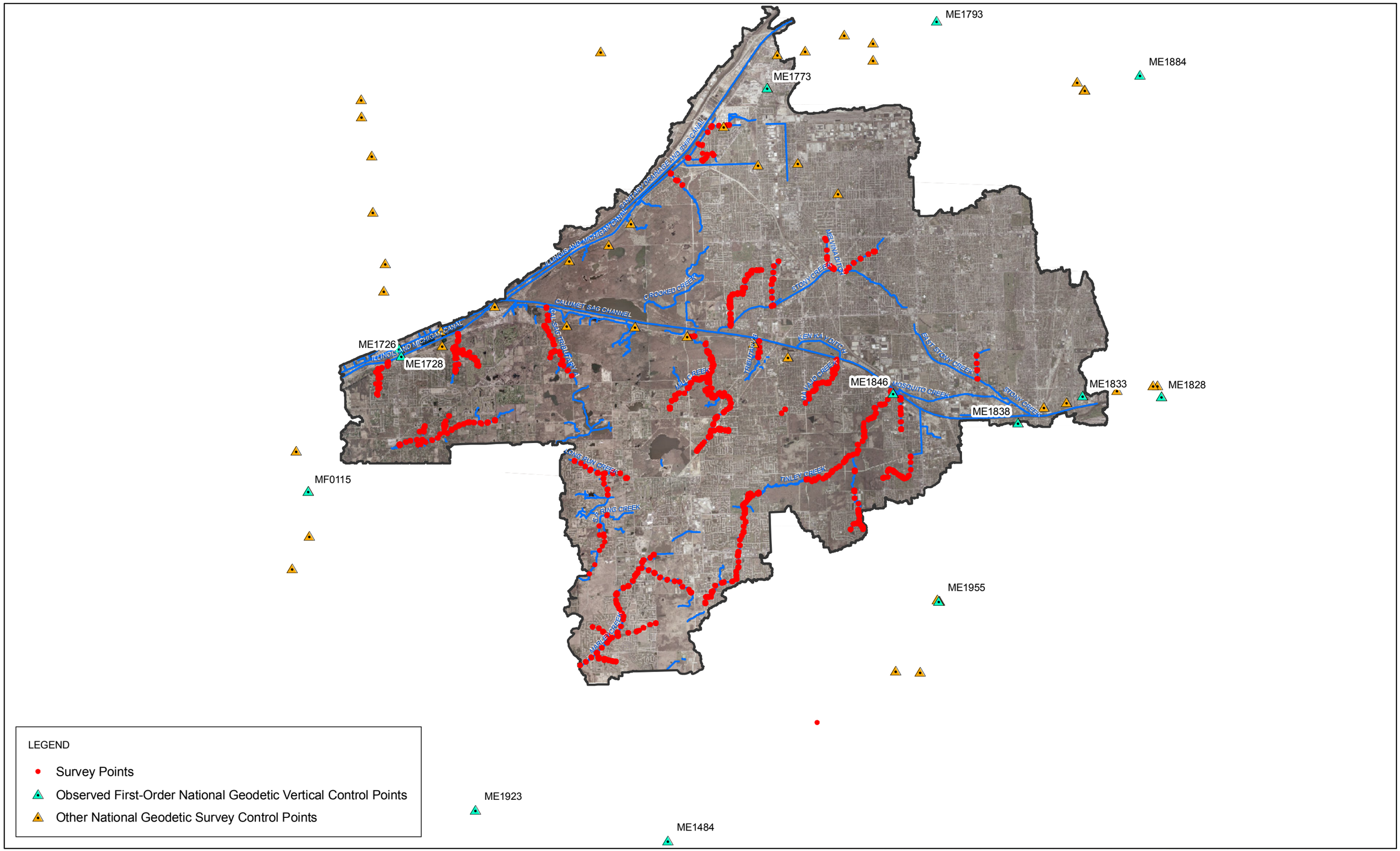
ME1793
ME1884
ME1773
ILLINOIS AND MICHIGAN CANAL
CHANNELIZED DRAINAGE DITCH
CALUMET SAG CHANNEL
CROOKED CREEK
STONY CREEK
NEW INN DITCH
ME1726
ME1728
CAL-SAG TRIBUTARY A
MILL CREEK
TRIBUTARY B
KENKAY DITCH
MAYLO CREEK
EAST STONY CREEK
ME1846
MOSQUITO CREEK
STONY CREEK
ME1833
ME1828
ME1838
MF0115
LONG RUN CREEK
TINLEY CREEK
SPRING CREEK
MAYLO CREEK
ME1955
ME1923
ME1484
LEGEND
Survey Points
Observed First-Order National Geodetic Vertical Control Points
Other National Geodetic Survey Control Points
N
0
1
2
Miles
DRAFT
Appendix D.1
Calumet-Sag Channel Watershed Survey Points
CH2MHILL

CERTIFICATION OF COMPLIANCE

Project Name:	MWRDGC - Calumet-Sag Watershed Plan Phase B
Statement/Agreement Date:	07/08/2007
Certification Date:	

Tasks/Activities Covered by This Certification (Check All That Apply)

☐	**Entire Project**
☒	**Survey**
☐	**Topographic Data Development**
☐	**Hydrologic and/or Hydraulic Analyses**
☐	**Coastal Flood Hazard Analyses**
☐	**Floodplain Mapping**
☐	**Other (Specify):**

This is to certify that the work summarized above was completed in accordance with the statement/agreement cited above and all amendments thereto, together with all such modifications, either written or oral, as directed by CH2M HILL, as such modifications affect the statement/agreement, and that all such work has been accomplished to meet accuracy guidelines contained in *Guidelines and Specifications for Flood Hazard Mapping Partners* cited in the survey scope of work document, and in accordance with sound and accepted engineering practices within the contract provisions for respective phases of the work. A discussion between CH2M HILL and NGS regarding NOAA NGS-58 occurred prior to the initiation of field surveys for this project. The discussion is documented in an internal technical memo (attached) which describes the survey procedures to be followed for this project. NGS stated that NOAA NGS 58 is a guideline, and that more recent developments in GPS technology permit the use of other techniques to achieve the same results; therefore, by signing this document the project surveyor agrees that complying with the survey procedures outlined in the technical memo will meet or exceed the final accuracy results specified in the FEMA guidelines and further confirm that their field surveyors have complied with the procedures outlined in the technical memo.

Name: Thomas J. Galbreath

Title: Survey Department Manager

Firm/Agency Represented: DB Sterlin Consultants, Inc.

Registration No.: 035-3134 Expires: 11/30/2008

THOMAS J. GALBREATH 035-003134 PROFESSIONAL LAND SURVEYOR STATE OF ILLINOIS AURORA, IL

Signature: Thomas J. Galbreath 03-05-2008

This form must be signed, stamped, and dated by the surveyor in responsible charge from the firm contracted to perform the work who is registered as a Professional Land Surveyor in the State of Illinois.

CERTIFICATION OF COMPLIANCE

Project Name:	Calumet-Sag Watershed Plan
Statement/Agreement Date:	Technical Memorandum guidelines August 10, 2007 (modified by EDI as attached)
Certification Date:	March 10, 2008

Mapping Activities Covered by This Certification (Check All That Apply):

☐	**Entire Project**
✸	**Survey**
☐	**Topographic Data Development**
☐	**Hydrologic and/or Hydraulic Analyses**
☐	**Coastal Flood Hazard Analyses**
☐	**Floodplain Mapping**
☐	**Other (Specify):**

This is to certify that the work summarized above was completed in accordance with the statement/agreement cited above and all amendments thereto, together with all such modifications, either written or oral, as directed by CH2M HILL, as such modifications affect the statement/agreement, and that all such work has been accomplished to meet accuracy guidelines contained in *Guidelines and Specifications for Flood Hazard Mapping Partners* cited in the survey scope of work document, and in accordance with sound and accepted engineering practices within the contract provisions for respective phases of the work. A discussion between CH2M HILL and NGS regarding NOAA NGS-58 occurred prior to the initiation of field surveys for this project. The discussion is documented in an internal technical memo (attached) which describes the survey procedures to be followed for this project. NGS stated that NOAA NGS 58 is a guideline, and that more recent developments in GPS technology permit the use of other techniques to achieve the same results; therefore, by signing this document the project surveyor agrees that complying with the survey procedures outlined in the technical memo will meet or exceed the final accuracy results specified in the FEMA guidelines and further confirm that their field surveyors have complied with the procedures outlined in the technical memo.

Name: Keith W. Stoddard

Title: Professional Land Surveyor

Firm/Agency Represented: Environmental Design International inc.

Registration No.: 3122

Signature: Keith W. Stoddard 3/10/08

PROFESSIONAL LAND SURVEYOR
KEITH W. STODDARD
NO. 3122
CHICAGO
STATE OF ILLINOIS

This form must be signed, stamped, and dated by the surveyor in responsible charge from the firm contracted to perform the work who is registered as a Professional Land Surveyor in the State of Illinois.

TECHNICAL MEMORANDUM **CH2MHILL**

Calumet-Sag Watershed Plan: Summary of Survey Procedures

PREPARED FOR:	Metropolitan Water Reclamation District of Greater Chicago
PREPARED BY:	R. Douglas Briggs/CH2M HILL Phil Blonn/CH2M HILL
COPIES:	Lance Vinsel/EDI Brad Hattendorf/DB Sterlin Bill Fox/CH2M HILL
DATE:	August 10, 2007
PROJECT NUMBER:	3060905.01.01

Purpose of the Technical Memo:

The purpose of this technical memo is to summarize basic procedures of the proposed ground survey.

These procedures will be used to meet the positional accuracy requirements as outlined in the FEMA *Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix A; Guidance for Aerial Mapping and Surveying.*

Due to recent advances in Real Time Kinematic (RTK) GPS methods, it seems clear that the positional horizontal and vertical accuracies required by the referenced FEMA report for field surveys can be achieved using this method. The Calumet-Sag survey team has discussed the referenced NOA NGS 58 report with Mr. Dave Conner of NGS, who agrees with this assessment, and has offered us the explanation that this document is to be used as a guide that does not prohibit the use of other newer technically acceptable methods to achieve the same results. Therefore, this document outlines the proposed method of using RTK GPS, as well as more traditional methods used to establish the control information.

1. Verification of the Virtual Reference System

The survey control for measuring the cross-sections on this project will be done using GPS Real Time Kinematic (RTK) methods employing a local Virtual Reference System (VRS). VRS is technology that utilizes a network of several continuously operating reference base stations to simultaneously calculate a GPS position on a point occupied by a GPS RTK rover receiver in the field. Accuracies of 1-cm horizontal and 2-cm vertical can be easily achieved using this methodology. These accuracies are well within those specified in the FEMA *Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix A; Guidance for Aerial Mapping and Surveying.*

Because this is relatively new technology and is not specifically mentioned in the FEMA guidelines as an acceptable methodology for field surveying we feel integrity checks on this local VRS network are necessary. These integrity checks will help support our position that the accuracies obtained using this methodology is within FEMA guidelines.

The integrity check will consist of observing National Geodetic Survey (NGS) control monuments while connected to the VRS and comparing our measured coordinate values against the published coordinate values. A minimum of ~~ten (10)~~ TWENTY-TWO (22) NGS monuments will be included in this survey, ~~a minimum of six horizontal control monuments of "B"~~ VERTICAL AND order or better ~~of the same epoch date and a minimum of 4 vertical control monuments of Second Order or better. The horizontal control monuments should be located such that 4 surround the project area and the other two (2) are evenly spaced in the approximated center of the project. The four vertical control monuments should be located such that they surround the entire project area.~~ KS

~~A minimum of four independent GPS RTK observations on each NGS monument will be conducted. These observations should take place on two different days. Two observations on each NGS monument will be conducted on each day with observations being at least 6 hours apart.~~ KS SEE EXHIBIT A VERIFICATION OF FEMA'S ACCURACY STANDARDS

Residuals will be computed using the difference between each measured ~~coordinate~~ ELEVATION value and the published ~~coordinate~~ ELEVATION value for each NGS monument. ~~Residuals for the X-coordinate, the Y-coordinate and elevations will be computed separately. Root Mean Square Error (RSME) will be calculated for each coordinate component (i.e. X-coordinate, Y-coordinate, and Elevation). Only the X coordinate and Y coordinate RSME needs to be calculated for the horizontal control monuments and~~ KS only the elevation RSME needs to be calculated for the vertical control monuments.

RSME will be calculated as follows:

RSME = Square Root of (Sum(R-M)^2)

Where:

RSME = root mean squared error

R = Published coordinate value

M = Measured coordinate value

These RSME values will then be used to assess the integrity of the VRS network. If the RSME values are less than ~~2 cm~~ KS the VRS will be deemed satisfactory for use on this project. If the RSME values are greater than ~~2 cm~~ KS then a more conventional GPS static network will be necessary to control the survey and the VRS will not be used. SEE EXHIBIT B FOR RESULTS. EXHIBITS A & B ATTACHED HERETO AND MADE A PART OF

1a. Alternate Static Control Method

In the event that the VRS system proves unworthy for use as control on this project an alternative Static GPS network will be established. Static GPS observations will be made on approximately thirty (30) control monuments spaced across the proposed watershed. A minimum of eight (8) of these monuments will be chosen so they are near the perimeter of the entire survey. The others will be selected so that they are approximately evenly spaced within the interior of the project. These monuments will be picked from the NGS data sheets. The final group of monuments that will be used will meet or exceed the criteria as outlined in the referenced FEMA guideline.

Once the Static GPS observations have been obtained and processed a minimally constrained least squares adjustment will be performed to test for the network integrity. If the results are within the 2-cm accuracy requirement the values of the minimally constrained adjustment will be applied to the primary control monuments and used for the remainder of the survey. The monument or monuments held will be provided so that the results of the minimally constrained adjustment may be replicated in the future.

When the final positions for the NGS monuments are established the monuments will then be observed with RTK GPS methods employing the VRS. Differences in the values obtained will then be incorporated into an adjustment factor for the VRS values. This adjustment factor will then be applied to all RTK GPS observations employing the VRS system.

In addition, a combined factor, or project adjustment factor will be calculated for the project to permit a seamless conversion between state plane grid and ground coordinates.

2. Secondary Control.

Secondary control points will be required on the project to survey the cross sections at the required interval along each stream. These points will be no greater than 1000 feet apart. The surveyors will use RTK GPS to establish the horizontal and vertical coordinate values on at least two (2) secondary control points along each stream. This information will be checked against the traditional total station methodology that will likely be used to set much of the secondary control network. These monuments will consist of a 5/8" diameter iron pipe or rebar 30" in length with a 2 ½" diameter aluminum cap installed on the top stating "Cal Sag Watershed Survey Traverse Point".

In some cases these secondary control points will also be verified with a closed loop differential level survey to the nearest acceptable NGS vertical control monument.

In instances where, due to obstructions such as tree cover, RTK GPS can only be utilized on one of the secondary control points along a reach of stream, then a traditional closed loop survey utilizing only total stations will need to be peformed to determine whether the survey is within the horizontal and vertical tolerances permitted by the project. This work will be checked to assure that it meets third-order surveying requirements as outlined in the scope of services.

The surveyors will also determine a second value on two of the secondary control points [1] using RTK GPS while either performing the survey an adjacent stream, or in a during a separate event. This will be performed to create a more complete network of verified control throughout the site, and to confirm whether the accuracy meets or exceeds the project requirements.

When several of the secondary control points are located in areas that are unobstructed, then the field surveyors will take measurements on the control points with RTK GPS twice, at least two (2) hours apart, to check the positional accuracy of the control points. While this more closely follows the procedure outlined in the FEMA guideline, this is an unlikely option due to the large amount of tree cover found at the site that will obstruct the satellite coverage and inhibit the use of RTK GPS.

3. Cross-sections

The stream cross-sections will be measured using conventional (Total Station) survey methods. Electronic data collectors will be used to record all survey data acquired during these surveys.

The total station will first be set up on the nearest secondary control point (section 2). A backsight will be made on another secondary or sub-control point. ~~The survey crew will then determine the location of the anchor point on the opposite side of the stream for that cross-section and read the horizontal and vertical coordinates of that point. They will then measure the horizontal angle to that point twice, both with the scope upright and inverted (double angles).~~ SECONDARY POINT SYNONYMOUS WITH ANCHOR POINT

Since the values established on these cross sections will be project adjusted state plane coordinates, and therefore can be easily replicated, the project team feels they will serve sufficiently as the anchor points without setting additional monuments at those locations. The project team is proposing this method because of the fact that most of the cross sections will generally not exceed 200 feet.

Measurements will then be made on the cross-section as outlined in FEMA *Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix A; Guidance for Aerial Mapping and Surveying.*

The next cross section will be determined by moving to the next secondary control point, taking a backsight on the previous control point, and repeating the previously described process.

Slope distances, vertical angles, horizontal distances, and vertical distances will all be reported for this process.

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[1] Collecting RTK GPS survey information for only one of the subcontrol points is acceptable in instances where tree cover does not permit collecting survey information on another point.

ATTACHMENT A

Calumet-Sag Watershed Plan Phase B

Topographic Data to Support Hydrologic and Hydraulic Modeling

Field Survey

Introduction

The field survey efforts described within this scope of work involve the collection of topographic and other physical data to support the development of hydrologic and hydraulic models for the evaluation of approximately 70 miles of streams and waterways located within the Calumet-Sag Watershed in southern Cook County.

Description of Work

The survey work for this project includes the following tasks outlined below. The **surveyor** shall comply with all further instructions by CH2M HILL during the life of the project. The major survey tasks shall include the following:

1. Use specific previously established Benchmarks from a list to be provided by CH2M HILL to establish control for all areas of the project to be surveyed. This should be done for each area of the project immediately prior to conducting the survey for that area. A control verification specification section has been added to this scope to provide guidance regarding the accuracy, precision, and type of control that is acceptable to this project. If additional control monuments need to be added, we have included a section specifying requirements for those monuments.

2. Perform transects (cross-sections) of each stream or waterway at the locations and for the extents indicated on mapping provided by CH2M HILL. The information provided by CH2M HILL will include approximate x and y coordinates of the point where each cross-section crosses the stream or waterway. The cross-section shall include x, y, and z coordinates of all "breakline" points along the cross-section. The cross-sections shall be taken such that they are perpendicular to the direction of flow. The cross-sections shall extend at least approximately 10-feet on either side of the channel overbanks. The cross-sections shall include stream channel bottoms that are under water (bathymetric survey). For small streams this could be accomplished by standing on the bank and placing the rod in the stream. For larger streams, this may require a boat and/or other equipment necessary for bathymetric surveys.

3. Collect bridge and hydraulic structure information including top of bridge elevations, low chord elevations, pier locations and pier width, bridge deck width, and other information as directed by CH2M HILL.

4. Take digital photographs of surveyed areas as directed by CH2M HILL.

5. Collect field notes recording other observed information as directed by CH2M HILL.

6. Provide all field notes, digital photographs, and data collected to CH2M HILL on a weekly basis as requested by CH2M HILL.

The surveyor shall then perform the following tasks:

1. Complete the remaining survey effort to the specifications outlined in this scope and in further direction provided by CH2M HILL

2. Provide all final deliverables for the project

Field survey work shall commence on 07/30/2007.

General Guidelines

Concerning the work outlined in this SOW, the **Surveyor** shall adhere to the following general guidelines:

1. The **Surveyor** shall take all reasonable precautions to prevent damage to public and private property, and shall restore the site to the condition existing prior to the **Surveyors'** entry.

2. All work shall be completed under the direction of a **Professional Land Surveyor** registered in the state where the work is being performed. It is the responsibility of the supervising **Land Surveyor** to ensure that all work under this agreement complies with all state and local regulations~~. All documents submitted shall bear the Surveyor's seal, signature, and a certificate that all work was done under the Surveyor's supervision and that all information contained in the document is true and is accurately shown.~~ KS

3. The **Surveyor** is responsible for quality assurance for the survey work performed on this project. The **Surveyor** shall provide a quality management plan (QMP) prior to the commencement of work for the project. The quality management plan should include field work checks, equipment calibration, office calculations, and a final peer review.

4. All work shall be conducted using equipment, personnel, and procedures that will ensure compliance with the accuracy standards as defined below.

Specifications of Work

Control Verification

The **Surveyor** shall determine and report the datum system of the previously established benchmarks provided by CH2M HILL. The survey shall conform to **NAD 83 (Latest Adjustment)** and **NAVD 88, Illinois State Plane Coordinate System, East Zone, 1201.**

Vertical Control work shall be Second Order Class II, as outlined in the **FGDC Geospatial Positioning Accuracy Standards, Part 4: Standards for Architecture, Engineering, Construction (A/E/C) and Facility Management.**

Horizontal Control work can be done using either standard surveying techniques or Global Positioning System (GPS) system techniques meeting the specification requirements outlined in this scope. If standard surveying techniques are used, all horizontal control work shall comply with Third Order Class I, as outlined in the **FGDC Geospatial**

Positioning Accuracy Standards, Part 4: Standards for Architecture, Engineering, Construction (A/E/C), and Facility Management.

If GPS is used, the relative horizontal accuracy shall conform to the **FGDC Geospatial Positioning Accuracy Standards, Part 2: National Standard for Spatial Data Accuracy for surveys having a positional accuracy of 1 cm.**

The **Surveyor** shall provide coordinates of all points X, Y, and Z to the nearest .01 foot, regardless of the accuracy of the survey.

THE UNITS OF MEASUREMENT FOR THIS PROJECT SHALL BE IN US SURVEY FEET.

Control Survey Scope of Work

1. Develop maps showing locations of control points (northings and eastings) with respect to key features, either manmade or natural, on the ground. In addition to the locations, also show ties with bearings and distances to existing control points that may be in the area.

2. The **Surveyor** shall provide all X, Y, and Z coordinates provided to the nearest 0.01 foot as specified above. The **Surveyor** shall confirm the relative accuracy of any existing benchmarks, and site control; and reestablish the project control to the accuracy standards outlined above.

3. ~~The Surveyor shall set or identify a minimum of four control points. The monuments set or identified shall be equally spaced approximating an approximate rectangle within the project area, but toward the perimeter of the survey if possible. The monuments shall meet the specified accuracy requirements for control monuments listed above. The monuments shall be 5/8 inch diameter iron pins 30 inches long with a plastic cap showing the Surveyor's registration number. Any federal, state, or local requirements may supersede this requirement. CH2M HILL must be notified immediately of any change.~~ KS

4. A CH2M HILL representative may be present at any time to coordinate survey activities and identify points and features to be located.

Transect and Bathymetric Survey

Specifications of Work

Vertical survey work for this part shall be Third Order, as outlined in the **FGDC Geospatial Positioning Accuracy Standards, Part 4: Standards for Architecture, Engineering, Construction (A/E/C) and Facility Management.**

Horizontal and vertical survey work can also be performed using either standard surveying techniques or Global Positioning System (GPS) system techniques meeting the specification requirements outlined in this scope.

If standard surveying techniques are used, all horizontal control work shall comply with Third Order Class II, as outlined in the **FGDC Geospatial Positioning Accuracy Standards,**

Part 4: Standards for Architecture, Engineering, Construction (A/E/C), and Facility Management.

If GPS is used, the relative horizontal accuracy shall conform to the **FGDC Geospatial Positioning Accuracy Standards, Part 2: National Standard for Spatial Data Accuracy, for surveys having a positional accuracy of 2 cm.**

The **Surveyor** shall provide coordinates in the **NAD 83 (Latest Adjustment)** and **NAVD 88, Illinois State Plane Coordinate System, South Zone, 1201** in use at this project. The **Surveyor** shall provide coordinates of all points X, Y, and Z to the nearest .01 foot, regardless of the accuracy of the survey.

The units of measurement for this project shall be in US Survey Feet.

Transect and Bathymetric Survey

Scope of Work

1. Conduct cross-section transect surveys along each stream at locations to be specified by CH2M HILL. Each transect shall be surveyed perpendicular to the flow of the stream at the location where the cross section is taken. The **Surveyor** shall locate three-dimensional coordinates at all break points along the reach of each stream. These cross sections shall include the following points:

    a. Thalweg or flow line elevation

    b. The edge of water

    c. Water surface

    d. Bottom of Bank

    e. Top of Bank

    f. 10-feet beyond the top of the bank, or to the next logical field determined breakline

2. In addition, at locations where structures such as bridges and large culverts cross the streams, the **Surveyor** shall:

    a. Verify the existing structures for hydraulic calculations, this includes the following:

        i. Elevation of flow lines,

        ii. Size of openings

        iii. Location of wing walls

        iv. Type of material along flow line

        v. Elevation of top of bridge

vi. Elevation of bridge low chord

vii. Pier widths and locations

viii. Other information as directed by CH2M HILL

3. The **Surveyor** shall also include X, Y, and Z coordinates shown as listed in the specification section of this scope, and in accordance with the above specified grid.

Bathymetric Survey Alternative

At locations where the streams are sufficiently large to preclude the use of standard survey methods, a bathymetric survey shall be provided.

General guidelines for the bathymetric survey have been outlined below:

1. The **Surveyor** shall supply CH2M HILL with the equipment type and specifications prior to commencing work on the bathymetric survey.

2. The proposed methodology for the bathymetric survey includes the use of RTK GPS, and aquatic depth finding equipment that meets the specifications for the positional accuracy and precision outlined within the topographic transect survey portion of the scope.

3. The bathymetric **Surveyor** shall determine the existing stream elevation at the day of the bathymetric survey. The information shall be properly correlated to determine the accuracy of the combination of below water surface and above water surface.

Field Survey Deliverables

1. The **Surveyor** shall provide a coordinate printout of all requested information, as listed in the description of work, in Excel format with all X, Y, and Z coordinates listed to the nearest 0.01 foot. The collected field information shall be provided in both Excel, and ASCII format; and shall contain the station ID and the horizontal and vertical coordinate information. All information shall be tied to the **Illinois State Plane Coordinate System, East Zone 1201.** ~~A project adjustment factor shall be provided and the final coordinate system shall be converted to ground.~~ KS

2. The **Surveyor** shall set and note the location of any additional control survey monuments required by the specification section of this scope.

3. All survey information shall be provided in a native MicroStation version 8 electronic drawing. The drawing shall show all information established and provided to the mapping consultant where applicable. All electronic drawing symbology shall conform to the **National CAD Standards (NCS), as published for the National Institute of Building Sciences.** If the **Surveyor** is unable to provide information to CH2M HILL in MicroStation Version 8 format, the CH2M HILL project manager shall be notified immediately.

4. The **Surveyor** shall provide their proposed feature codes to CH2M HILL one week prior to commencing work on the project. The feature codes will be reviewed to assure

conformance to the **National CAD Standards, FEMA** guidelines, and other project requirements. Any revisions to the proposed feature codes, by CH2M HILL or the project client, shall not constitute reason for additional compensation to the **Surveyor**.

5. The **Surveyor** shall provide two digital photographs taken at each cross-section surveyed (one looking upstream and one looking downstream). The **Surveyor** shall also provide at least two digital photographs of each bridge, culvert, or other structure surveyed (one photograph of the upstream side of the bridge, culvert, or other structure, and one photograph of the downstream side of the bridge, culvert, or other structure, and additional photographs as needed.

6. The **Surveyor** shall provide all field notes taken that document work performed and observations made while performing field survey work.

Additional Reference and Guideline Section

The field survey shall also meet or exceed the **Flood Emergency Management Agency's Guidelines and Specifications for Flood Hazard Mapping Partners**, Final, May of 2005.

Specific sections of particular importance are listed below:

Appendix N: Data Capture Standards

Appendix N: Data Capture Guidelines

Appendix A: Guidance for Aerial and Mapping Surveying

Health and Safety Requirements

The **Surveyor** shall provide and assume responsibility for adequate health and safety protection for onsite personnel. CH2M HILL requires contracted **Surveyors** to provide evidence of having received OSHA-specified training to conduct work on potentially hazardous sites. The specific content of the training requirements is outlined in 29 CFR 1910.120(e). Standard personal safety equipment including: hardhat, safety glasses, steel-toed boots, gloves, and coveralls are recommended for all project activities.

The **Surveyor** shall provide CH2M HILL's office with copies of current training and medical certifications, and shall insure that this documentation accompanies their personnel onto job sites for any work authorized under this agreement.

All **Surveyor** on-site personnel will be required to attend a brief (30-minute) on-site health and safety meeting on the first day of work and will be required to review, sign, and follow the CH2M HILL health and safety plan developed specifically for this project. The CH2M HILL health and safety plan will address standards to be followed regarding traffic safety, working near or in water, encountering dogs or wildlife, and general field work safety procedures.

Surveyor personnel showing indications of being under the influence of alcohol or illegal drugs will be sent off the job site and their employer will be notified. **Surveyor** personnel under the influence of prescription or over-the-counter medication that may impair their ability to safely and correctly operate the equipment necessary to do their job are required to

identify this condition to CH2M HILL or their employer. It is expected that the **Surveyor** will assign them other work and provide a capable replacement (if necessary) to operate the equipment to continue work.

DRAFT - Calumet-Sag Detailed Watershed Plan Field Survey Standards and Guidance

Introduction

The purpose of this document is to provide the necessary surveying methods and standards information required for the execution and completion of field survey data collection for the Calumet-Sag Detailed Watershed Plan project.

This document is not intended to replace the actual scope of services, but is intended to supplement the scope in order to clarify the CH2M HILL's project expectations regarding the proposed survey procedures.

This project when completed will reduce property damage and road closures due to flooding. The surveying information gathered will entered as input for models used to locate flood prone areas and evaluate alternative improvement projects.

Field Notes

Information required to properly model stream flow and flooding conditions are elevations to create a profile of the cross-section of the stream and photographs of the condition and vegetation for each cross-section. Provide survey notes and photos regarding observations of any obstructions in the floodplain (including structures such as houses or barns), general description of vegetation type (e.g. 12-inch tall grass, dense blackberry cover, willow sprigs, etc.), bent locations and type (rounded, square, columns, etc.), high water marks, evidence of erosion or scouring. Record size and elevation data for any upstream or downstream culverts or bridge structures on the study channel. Call if you have questions about whether something might be important to survey. Make note or take photo of observed conditions if the budget or time doesn't allow surveying them.

The following should be included in field notes:

- Starting location of day (first cross-section #)
- Control points
- Vegetation surrounding each cross-section
- Land use or description of buildings surrounding each cross-section
- Note any buildings or obstructions within channel or floodplain area

Benchmark and Control

Preferably, the reference benchmarks created during the Cook County aerial mapping project that was completed in 2003 should be used. A total of 135 control points were established. Of these, 25 are National Geodetic Survey (NGS)/High Accuracy Reference

Network (HARN) control stations that are located within Cook County and its vicinity. The remaining points were either existing or new points identified as photo control specifically for the mapping project. Existing NGS monuments within the region were reviewed and referenced to HARN.

The horizontal ground control was established by GPS technology, and horizontal positioning accuracy meets the specifications of the Federal Geodetic Control Subcommittee (FGCS) Second Order Class One. The Cook County Mapping Services department maintains a GIS shapefile containing all of the ground control points.

As stated in the scope, the surveyor is expected to confirm the datum used by Cook County, and provide calibration and post-processing reports of the referenced benchmarks so that the accuracy and precision of the benchmarks can be determined, as well as the relative positional accuracy between the benchmarks.

Datum

Survey standards should be consistent with FEMA's *Guidelines and Specifications for Flood Hazard Mapping Partners*, Appendix A, "Guidance for Aerial Mapping and Surveying".

Field surveys performed to support Phase B of the Calumet-Sag DWP development will be consistent with survey requirements identified in Chapter 6 of the CCSMP. However, it should be noted that." FEMA survey standards require the horizontal control/datum to be the National American Datum of 1983 (NAD1983) and the vertical datum to be the North American Vertical Datum of 1988 (NAVD). If models developed as a part of District DWP development are utilized for future floodplain mapping activities, some conversion may be required to be consistent with FEMA standards.

All points surveyed shall be georeferenced so that the data can be brought into GIS.

TABLE 6.9 Watershed Data Development Standards And Specifications

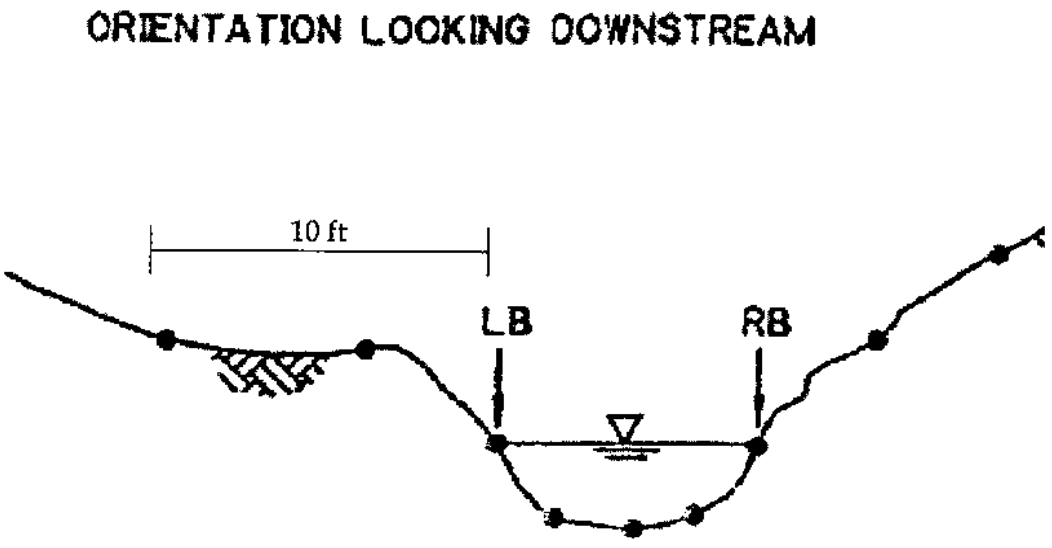
DATA TYPE	STANDARDS DOCUMENTATION	SUMMARY
GIS Data	District GIS Data Development Standards	Data developed to support DWP will be consistent with latest available District GIS Standards and Specifications.
Survey Data	District Vertical Datum	DWP will contain a survey standards document subject to District review prior to initiating any field surveys. If necessary, the District may allow changes to these standards in order to be consistent with unique conditions in watersheds such as those that have upstream or downstream boundary condition models that have been developed in a different coordinate system.
Survey Data	FEMA Guidelines	Survey standards will be consistent with FEMA's Guidelines and Specifications for Flood Hazard Mapping Partners, Appendix A, "Guidance for Aerial Mapping and Surveying," located in Appendix D and available at www.fema.gov/fhm/dl_cgs.shtml
DWP Data	Cook County Stormwater Management Plan	All data developed to support DWP will be consistent with standards provided as a part of this document, or other scoping documents provided by the District.

It should be noted that within the above referenced FEMA guidelines, and also within our scope, the documents that are referenced for survey accuracy, precision, and survey procedures are:

- FGDC **Geospatial Positioning Accuracy Standards, Part 4: Standards for Architecture, Engineering, Construction (A/E/C) and Facility Management**
- FGDC **Geospatial Positioning Accuracy Standards, Part 2: National Standard for Spatial Data Accuracy**

Stream Cross-Section Surveys

For each stream, a map has been provided marking preferred locations where cross-sections are to be surveyed along with approximate x and y coordinates. The map should be used as a guideline for surveying locations. If any points along the stream have a significant change in geometry or characteristics, these points should be surveyed as well. Each cross-section survey should contain ID #, significant elevations to depict the cross-section, a photograph and rough sketch depicting the cross section and its location which includes a north arrow and direction of flow. Vegetation in the area should be noted along with any nearby buildings, and any other general notes on the condition of the stream (erosion, scouring, excessive amounts of debris). Surveys should be conducted to define the main channel of the stream only and should extend at least approximately 10 feet beyond the channel overbank.

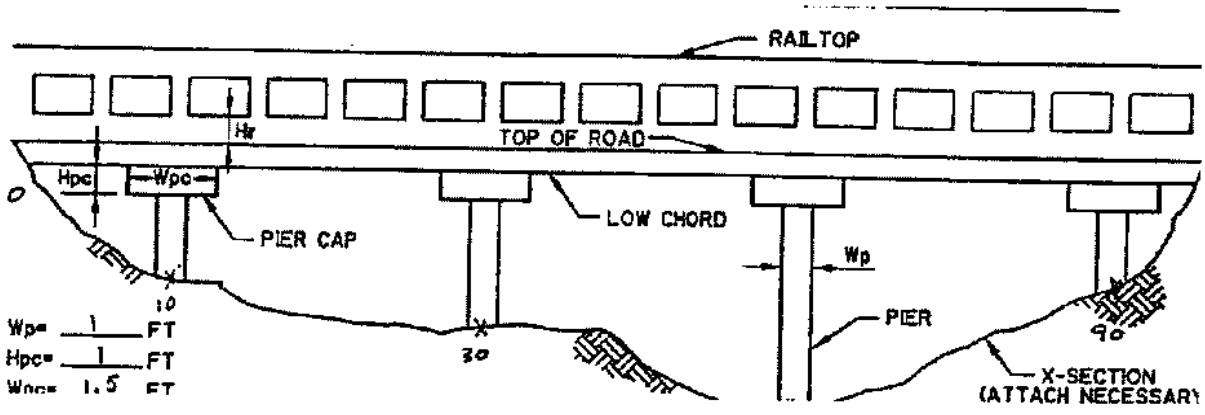


Smaller streams can use a GPS surveying method or simply submerging the surveying rod from the bank. With larger streams it is recommended the bathymetric method be used.

Bridge and Culvert Surveys

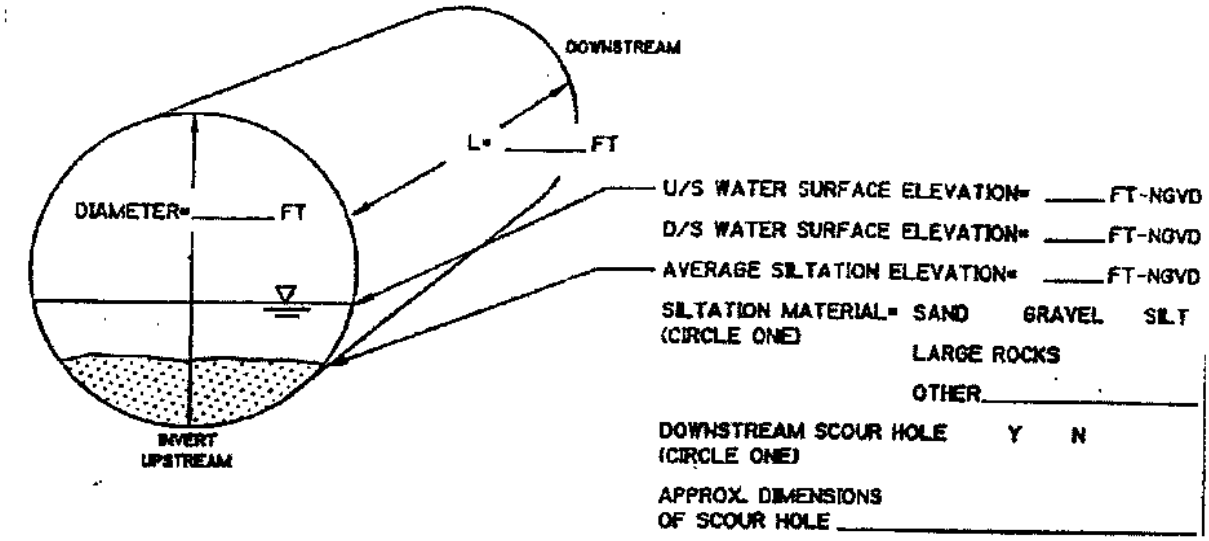
Generally, cross-sections of the stream should be taken directly upstream and downstream and downstream four bridge/culvert widths and upstream one bridge/culvert width (see map for locations) of all bridges and culverts. The location of these sections can be modified to capture important stream characteristics such as changes in slope, channel bottom width, vegetation, tributary confluences, etc. The four sections immediately surrounding the bridge should be kept close to the configuration described above.

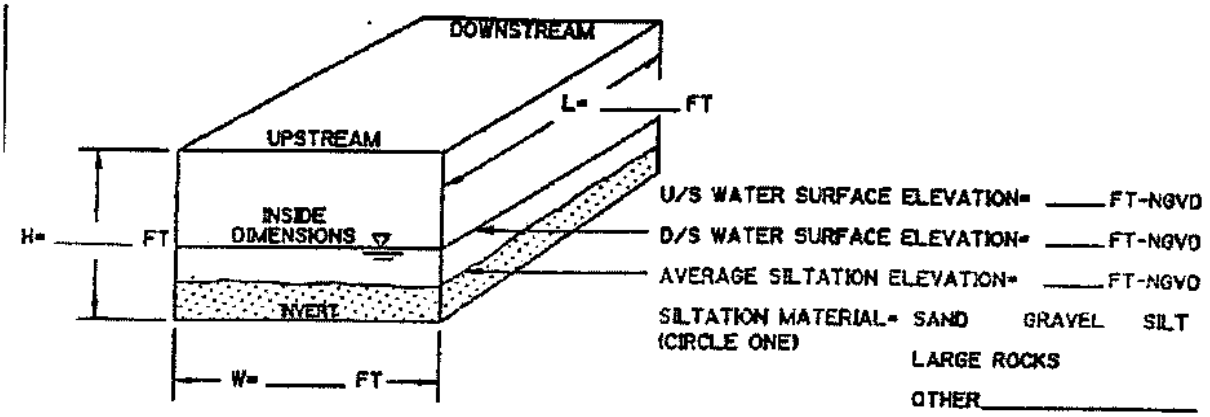
- Take measure of the opening on the upstream and downstream side of the bridge at 5' or 10' intervals.
- Must get accurate stream bed profile.
- Get lowest elevation of the low chord.
- Measure and describe abutments, wingwalls, aprons, etc.
- Take elevations at highest point of bridge. This is most likely either the centerline or rail top.
- A sketch (copy) should be attached to this report.
- Note characteristics of streambed material. Is there a portion of rip-rap or concrete section of channel under the bridge?



When surveying typical circular or box culverts include the invert elevations for both the upstream and downstream ends, water surface elevation, upstream and downstream, and average siltation elevation. Also include diameter or height and width of opening if there are identical culverts, only the dimensions of one need to be included along with the number of identical culverts. Survey the head wall elevation and note the material, condition, and type of head wall (upstream). If any scour hole exists downstream the dimensions of the hole should be noted. Any general observations made out in the field not mentioned above that may affect the flow of water such as overgrown vegetation or

excessive debris should be included as well. See the diagrams below as a basic guideline for dimensions.





Photographs

Surveyors should take digital photographs at each cross-section location. These photos if possible should include a whiteboard indicating the ID number of the cross-section along with a survey rod for scale to help identify which photos belong to each section. Each photograph should include a description of the item(s) shown. Photographs of all existing structures including culverts, bridges, or any other structure that could restrict the flow of water in the event of high water levels looking at the structure from both an upstream and downstream position and additional photos of any points of erosion/scour or possible problem areas should also be included as well.

Quality Assurance Plan:

The surveyor shall develop a quality assurance/quality control plan describing proposed survey methods to be used at the site.

Specifically, the surveyor shall describe proposed methods to back check their field work. These methods will include, but are not limited to the use of closed loops and check shots.

Once the data is collected, the surveyor shall also perform office checks of the data before presenting it to CH2M HILL. This again should involve, but is not limited to cross checking plan information against the field notes, and verifying how well their loops and check shots closed. If closure errors are found in excess of those specified by the scope, the surveyor is expected to correct those errors before continuing with additional survey work.

Also, it is strongly recommended that each day a minimum of three points from the previous day's work be reshot and confirmed prior to beginning the new day's field work.

If for some reason the surveyor cannot reconcile discrepancies noted in the quality assurance process, CH2M HILL shall be notified immediately.

Deliverables

Specifics regarding deliverables are outlined in the survey scope.

As outlined in the survey scope, the surveyor shall provide weekly deliverables and a diary of events from the previous week.

The surveyor is expected to contact CH2M HILL for guidance if he or she experiences difficulties or needs clarification on specific items to be located that are not directly stated within the scope of services.

EXHIBIT A

Verification of FEMA's Accuracy Standards

It is the Client's desire that the survey data meet the accuracy requirements of FEMA's *Guidelines and Specifications for Flood Hazard Mapping, Appendix A: Guidance for Aerial Mapping (FEMA Appendix A).*

FEMA Appendix A has three basic requirements for ground control surveys; NSRS, Horizontal Control, Vertical Control.

NSRS - All data must be connected to the National Spatial Reference System (NSRS).

Our survey is connected to a system of continuously Operating Reference Stations (CORS) by way of *GPS SpiderNET/VRS.* These CORS stations and the SpiderNET/VRS itself are supplying the latest data for the NSRS.

Horizontal Control - The horizontal control must be to NGS second order or better accuracy.

As stated in *FEMA Appendix A,* these accuracies are easily obtainable when the required vertical accuracies are obtained.

Vertical Control - The vertical control must use 5-centimeter or better GPS procedures.

FEMA Appendix A states that the procedures specified in *NOAA Technical Memorandum NOS NGS-58* (NGS-58) need to be followed to achieve 5-centimeter accuracies.

Since the writing of *FEMA Appendix A* and *NGS-58,* GPS technology has advanced considerably. With the advent of multiple CORS stations, High Accuracy Network RTK (SpiderNET/VRS) and more accurate geoid models (GEOID03), 5-centimeter accuracy is obtainable by the use of Real-Time Kinematic (RTK) methods in areas of good CORS coverage.

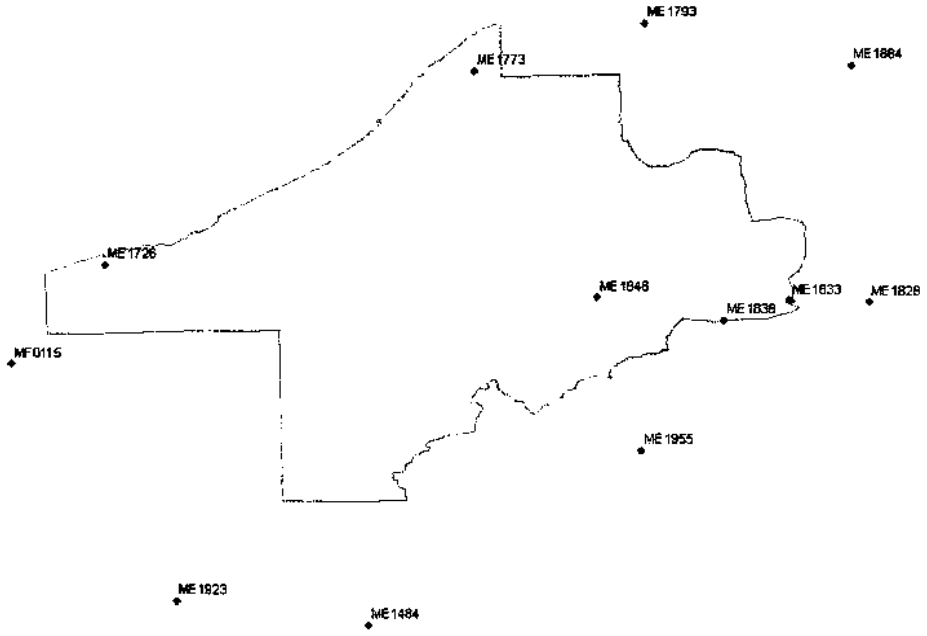
We used SpiderNET/VRS to set all of the control for the ground surveys on this project. No technical paper is available to specify the procedures necessary to obtain 5-centimeter accuracies using SpiderNET/VRS. We determined to demonstrate that the SpiderNET/VRS systems provide 5-centimeter accuracies for the project area.

We tested our methods by using the procedure outlined in *Part 3: National Standard for Spatial Data Accuracy (NSSDA).*

5-centimeter Accuracy Test

As specified in NSSDA, a minimum of 20 points need to be tested to achieve the required 95% confidence level. Our test uses twelve first order benchmarks. Most of the benchmarks were observed twice with exception of ME1793 and ME1884 which were only surveyed once due to problems getting a GPS signal. The test involved 22 total observations. Duplicate observations were taken on different days and at different times of the day as specified in NGS-58.

These tests were made using the same procedures used for the Local Control Points established for the project cross-sections. The first order benchmarks were distributed in and around the project as shown.



The method of surveying the Local Control Stations requires that each point be surveyed twice with different satellite configurations. If the difference in elevation between the two values is more than 10cm, the point is surveyed again until a less than 10cm difference is established between two readings. An average of the two elevations is then used as the Local Control Station Elevation.

Similarly, the test observations followed the same method until two readings were within 10cm. No two test observations were more than 10cm apart, both values were used in the accuracy calculations. The accuracy calculations analyzed the difference between each observed elevation and the NSRS published values for the

benchmarks. A spreadsheet similar to the examples in NSSDA was used for the analysis (see attached Exhibit B).

Therefore, the accuracy value according to the NSSDA, at 95% confidence, is 5 centimeters. Of the twenty two observations tested, only ME1838 has a positional error that exceeds 5 cm.

Each observation in the test was analyzed. For the project local control points (secondary /anchor points) the two observations were averaged, thereby obtaining even more accurate results.

EXHIBIT B

	Point Id	Monument NAVD 88 Published Orthometric Elevation (m)	Monument NAVD 88 Calculated Orthometric Elevation (ft)	Project NAVD 88 Leveled Orthometric Elevation (Project BM or Original BM) (ft)	RTK Observed Orthometric Height (ft)	Difference (ft)	Difference (cm) (Positional Error)	Difference Squared (cm)
1	ME1484	231.362	759.060	759.060	759.207	-0.147	-4.5	20.1
2	ME1484 B	231.362	759.060	759.060	759.150	-0.090	-2.7	7.4
3	ME1726	182.107	597.463	595.186	595.122	0.064	1.9	3.8
4	ME1726 B	182.107	597.463	595.186	595.104	0.082	2.5	6.2
5	ME1773	183.610	602.394	601.682	601.733	-0.051	-1.6	2.4
6	ME1773 B	183.610	602.394	601.682	601.678	0.004	0.1	0.0
7	ME1793	183.569	602.259	601.421	601.394	0.027	0.8	0.7
8	ME1828	180.255	591.387	590.537	590.532	0.004	0.1	0.0
9	ME1828 B	180.255	591.387	590.537	590.559	-0.022	-0.7	0.4
10	ME1833	184.394	604.966	603.563	603.494	0.069	2.1	4.5
11	ME1833 B	184.394	604.966	603.563	603.548	0.015	0.5	0.2
12	ME1838	181.772	596.364	594.294	594.058	0.236	7.2	51.7
13	ME1838 B	181.772	596.364	594.294	594.227	0.067	2.0	4.1
14	ME1846	183.854	603.194	603.194	603.128	0.066	2.0	4.1
15	ME1846 B	183.854	603.194	603.194	603.206	-0.012	-0.4	0.1
16	ME1884	185.841	609.713	609.713	609.782	-0.068	-2.1	4.3
17	ME1923	214.366	703.299	703.299	703.258	0.041	1.3	1.6
18	ME1923 B	214.366	703.299	703.299	703.219	0.080	2.4	6.0
19	ME1955	209.188	686.311	686.311	686.442	-0.131	-4.0	15.9
20	ME1955 B	209.188	686.311	686.311	686.407	-0.096	-2.9	8.6
21	MF0115	185.747	609.405	609.405	609.469	-0.064	-1.9	3.8
22	MF0115 B	185.747	609.405	609.405	609.316	0.089	2.7	7.4

Sum	153.3
Average	7.0
RMSE (cm)	2.6
Accuracy (cm)	5