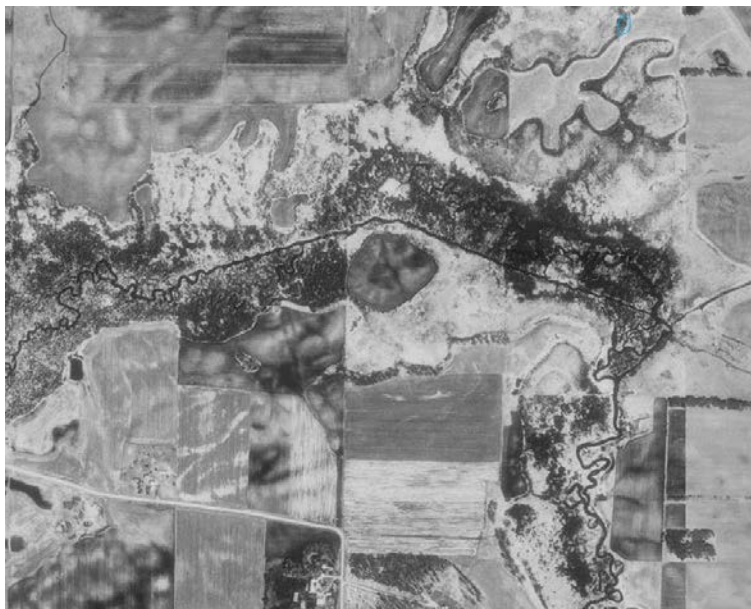


Altered Watercourse Determination Methodology



Final Revision (8)

**Minnesota Geospatial Information Office (MnGeo)
For
Minnesota Pollution Control Agency (MPCA)
June, 2013**

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Summary

The Altered Watercourse Project was a concerted effort between the Minnesota Pollution Control Agency (MPCA) and Minnesota Geospatial Information Office (MnGeo) to create a statewide inventory of streams that have been hydrologically altered (e.g. channelized, ditched or impounded). The data were created in support of the MPCA's water quality monitoring and assessment program and provided information about stream habitats that have been compromised through such alteration.

The project entailed digitization of Geographic Information System (GIS) 'events' on to the United States Geological Survey's National Hydrography Dataset (NHD) stream linework. The events were then categorized as one of four types: *Altered*, *Natural*, *Impounded* or *No definable channel* based upon a standardized methodology and criteria. These categorizations were performed manually by GIS technicians using visual interpretation of multiple years of aerial photography; LiDAR (Light Detection And Ranging) derived hillshade imagery and various other reference data in ArcGIS 10.0.

In 2008 a Pilot Project was performed on three HUC-8 (USGS 8-digit Hydrologic Unit Code) watersheds in Minnesota to ascertain the feasibility of developing and using a standardized methodology to determine altered watercourses. Information learned from the Pilot Project resulted in an updated methodology, new ArcGIS tools and the gathering of new reference data for the statewide Altered Watercourse Project that commenced in April 2011.

The first phase of the project was a parallel test of 50 selected HUC-12 (12-digit) watersheds performed by two GIS technicians to determine if the updated methodology produced similar results in identical locations. Upon completion of this phase the methodology was further refined and the statewide phase of the project started in April 2012.

This phase involved the completion of the 80 HUC-8s containing all the stream events in Minnesota by June 2013. Many personnel were employed in the creation and review of these Altered Watercourse events at MnGeo and MPCA, respectively. By the end of the project over 169,841 km (105,534 miles) of streams had been categorized.

Introduction

These are the procedures and criteria (i.e. methodology) for determining altered watercourses using the National Hydrographic Dataset (NHD) for Minnesota with ArcGIS 10.0.

By definition an *altered watercourse* is any stream whose habitat has been compromised through hydrological alteration. These include canals and ditches artificially constructed as well as natural streams and rivers whose channels are visibly modified. Basically, anywhere a backhoe has been used to create a ditch or straighten a stream can a watercourse be considered *altered*. However, for the purposes of this project, watercourses that have been dredged, had rip-rap added or debris removed do not count as *altered*.

In addition to altered watercourses are those streams whose flow has been dammed for human purposes. These *impounded* watercourses are distinguished from *altered* watercourses in that, although they were created by people, their channels (or shorelines) were usually formed by the natural rise of the impounded water level and not by deliberate alteration.

The *No definable channel* category was developed to represent NHD Flowlines that no longer appear in the aerial imagery or LiDAR hillshade or are insufficient watercourses for MPCA purposes. Examples include flowlines through lakes or wetlands, storm water pipelines and grassy swales in farm country.

Finally, those watercourses of the state that fit none of the above definitions are considered *natural* with little to no human physical influence.

Conventions used in this document:

- All file paths prefixed with ...\
Services\Projects\Altered_Watercourses\Statewide_Project_2010_2011\Working
- **AW** is an abbreviation for **Altered Watercourse**
- **HEM** is an abbreviation for **Hydrography Event Management**
- **HUC-8s** are the 8-digit Hydrologic Unit Code watersheds developed by the USGS that are used to parse data for this project.
- **Analyst** refers to the editor or delineator of the HUC-8 Altered Watercourse layer

PC Setup

The first three steps need to be done only once for each PC on which Altered Watercourse edits will be performed. **Step 4 will need to be done every time its associated tool is updated.**

1. Install ArcGIS 10.0 (with Python 2.6).
2. Copy, unzip and install the Hydrography Event Management (HEM) tool (v 2.5) from the ...*HEM* directory. Note: The included ReadMe.txt file which shows how to install/uninstall is incorrect for Windows 7 OS, use Install_w_Windows7.txt in the ...*HEM* directory instead. The Help.chm file contains other info.
3. Open ...*ConnectionsNeeded.docx* and verify your PC has the included connections in both ArcCatalog and Windows Explorer.
4. Remove *Altered Watercourse Tools* toolbox from ArcToolbox if it exists then re-add the *AW Tools.tbx* toolbox file from the ...*AWToolbox* directory.

AW Editing Setup

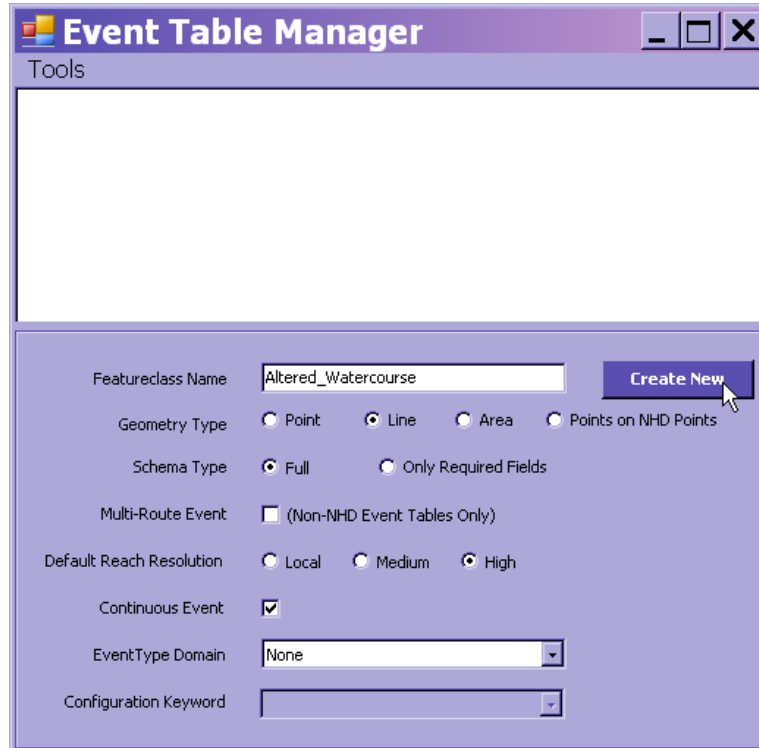
The following procedure shows how to set up and configure the Altered Watercourse data and toolbar for each geodatabase.

1. Copy the NHD personal geodatabase that the analyst wishes to work on from the drive mapped to \\geoint.lmic.state.mn.us\s3\gisdata\Inland Waters\nhd_awat_hucs_statewide\ to a local directory.
2. Open ArcCatalog and select the given geodatabase.
3. Click on the Event Feature Class Manager button of the Hydro Event Manager toolbar:



4. Select Tools > Add New menu items.

5. The following dialog will appear. Fill in exactly as shown:



6. Click Create New button.
7. For ArcGIS 10.0, import the Spatial Reference from its associated NHDFlowline feature class.
8. Accept default values in subsequent Spatial Reference dialogs.
9. Close the Event Feature Class Manager dialog when done. After refreshing, the *Altered_Watercourse* feature class should appear at the root level of the given personal geodatabase in ArcCatalog.¹
10. In ArcToolbox, run the *Set Up Altered Watercourse* script in the *Altered Watercourse Tools* toolbox. Input the personal geodatabase that contains the just-created *Altered_Watercourse* feature class.

¹ The tool also creates the metadata tables: *HEM_EVENT_TABLES*, *HEMFeaturetoMetadata*, *HEMMetadata*, *HEMMetadataIDs* and *HEMSourceCitation* at the root level.

11. This script will add the following fields and domains needed by the Altered Watercourse toolbar:

Field						Domain	
Name	Alias	Type	Width	Description	Required	Name	Values
AWEvtType	AW Type	Short-Int	N/A	Type of AW Event	Yes	AW Event Type	1=Altered; 2=Natural; 3=Impounded; 4=No definable channel
Confidence	AW Confidence	Short-Int	N/A	Confidence level of chosen event type	Yes	AW Event Confidence	1=Low; 2=Medium; 3=High
NHDUpdate	AW NHD Update Type	Short-Int	N/A	Suggested type of NHDFlowline update	Yes	AW NHD Update Type	1=None; 2=Add; 3=Delete; 4=Change FType; 5=Change Geometry; 6=Other
Notes	AW Notes	Text	255	AW Event comments	No	N/A	N/A
CritLetter	AW Criteria Letter	Text	1	AW Criteria letter used to determine event type	Yes	AW Criteria Letter	A - N
CritNum1	AW Criteria Number 1	Short-Int	N/A	First AW Criteria number used to determine event type	Only for certain CritLetters	AW Criteria Number	Altered Criteria: 1-9, 11-18; No definable channel Criteria 21-27; Impounded Criteria: 31-39
CritNum2	AW Criteria Number 2	Short-Int	N/A	Second AW Criteria number used to determine event type	Only for certain CritLetters	AW Criteria Number	Altered Criteria: 1-9, 11-18; No definable channel Criteria 21-27; Impounded Criteria: 31-39
CritNum3	AW Criteria Number 3	Short-Int	N/A	Third AW Criteria number used to determine event type	Only for certain CritLetters	AW Criteria Number	Altered Criteria: 1-9, 11-18; No definable channel Criteria 21-27; Impounded Criteria: 31-39

12. Start ArcMap.

13. Make HEM Toolbar visible by clicking the menu items: Customize > Toolbars > Hydro Event Management Tools

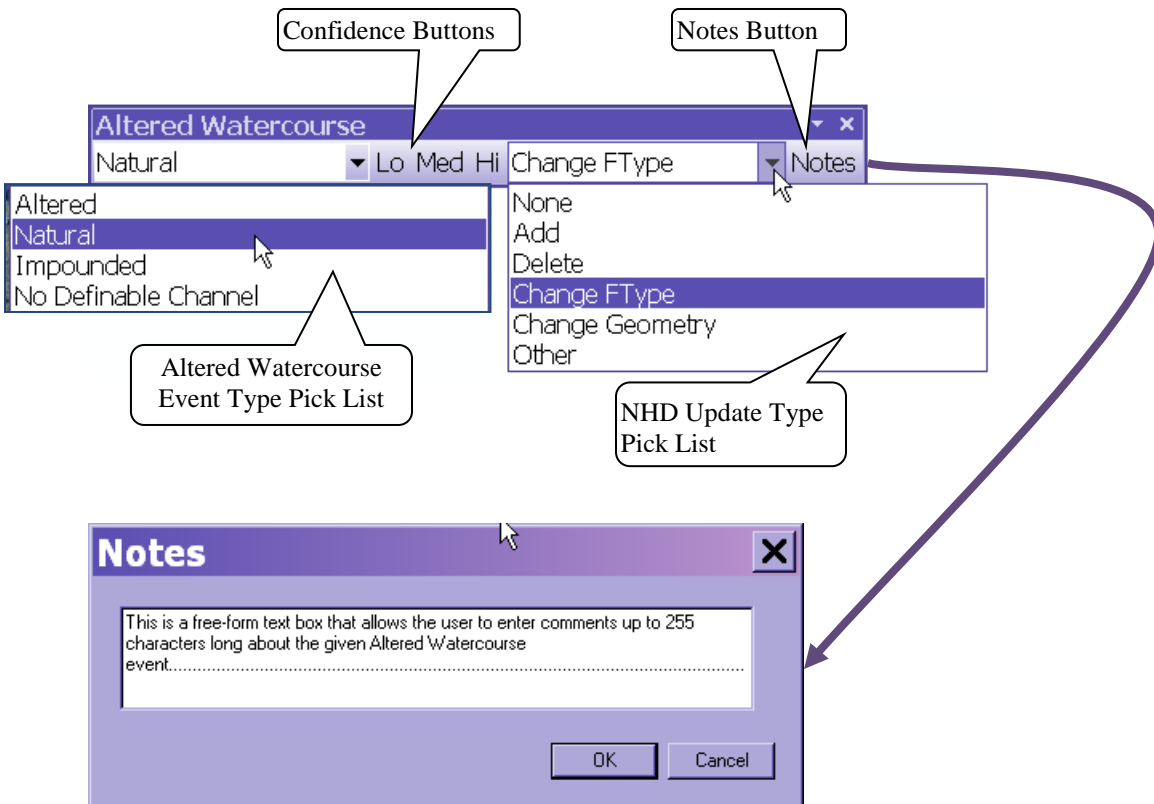
14. Load the Altered Watercourse toolbar, click the menu items: Customize > Add-In Manager... > Options (tab) > Add Folder (button)

15. Enter the folder: ...*add-in*

16. Click the Add-Ins tab to verify that the *Altered Watercourse* add-in loaded properly.

17. Make the AW toolbar visible by clicking the menu items: Customize > Toolbars > Altered Watercourse

18. The following figure shows the Altered Watercourse toolbar and its various tools:



The designation of watercourses in the Altered Watercourse Project essentially follows a two-step process:

First, what's known as an event feature is created corresponding to each NHDFlowline feature using the **Hydro Event Management** toolbar. Then, attributes are added to each event using the **Altered Watercourse** toolbar designating it as either **Altered**, **Natural**, **Impounded** or **No Definable Channel** along with the confidence level for this designation and what kind of updates may be necessary for the NHDFlowline data. The AW toolbar also allows the addition of comments or notes.

ArcMap Setup

The following contains the toolbars to be used in ArcMap 10.x for Altered Watercourse determination.

Toolbars

Hydro Event Management (HEM) Tools (v 2.5)
Altered Watercourse
Editor
Standard
Tools

Status Tracking

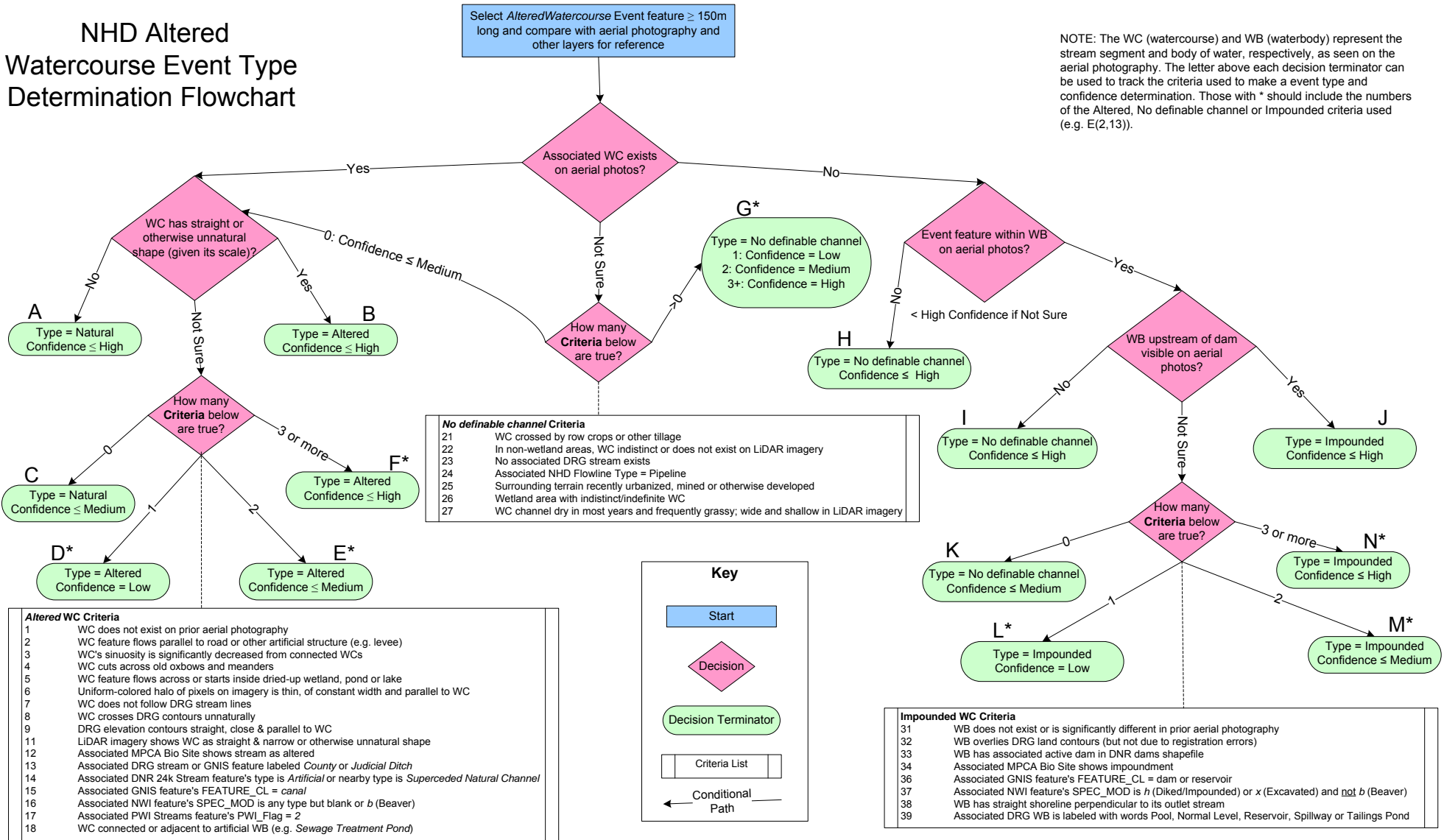
A Google Docs spreadsheet file (*Status*) has been set up to track status and basic metadata for the statewide HUC-8 phase.

1. Click **Status** to open the spreadsheet file in a web browser and go to the **HUC-8s** tab. Note that the HUC-8s are grouped in order of chronological importance with the red Priority ones listed first.
2. Enter the analyst's initials in the **Staff** column for the chosen HUC-8 along with today's date in the **Date Started** column under **Initial Edits**.
3. Fill in the **NHD Version** from the Version parameter value found in the NHDProcessingParameters table in the given HUC-8's NHD geodatabase.
4. Keep track of the number of hours it takes to complete the given HUC-8 and enter this amount in the **Hours to Complete** column under **Initial Edits**.
5. Also fill in the **Date Completed** column under **Initial Edits** when editing is finished.
6. If any corrections to the HUC-8 are necessary, fill in the **Date Started**, **Date Completed** and **Hours to Complete** columns under **Correction Edits** similarly.
7. If there were any disagreements with MPCA corrections add "Yes" under the **Any Disagreements with MPCA comments?** column, otherwise add "No".

Creating and Designating AW Events

1. In ArcMap, load the working layers (shaded blue in [Appendix E](#)) from the chosen HUC-8 personal geodatabase. Note: Load Altered_Watercourse layer below the NHDFlowline layer.
2. For each of these layers import the symbology from its associated layer file found in ...*layer_files*.
3. Load the **Reference.lyr** layer file found in the directory given in step 2. This will load all necessary reference layers needed for AW editing ([Appendix E](#)).
4. Open **Status** in a web browser and go to the **Layer Overlap** tab. Note which aerial photography, LiDAR hillshade and vector reference layers overlap the chosen HUC-8.
5. If a completed HUC-12 from the QA/QC phase overlaps the chosen HUC-8 (see **Completed HUC-12 (from QA/QC)** column – header is highlighted yellow) then make visible the *Completed HUC-12s* layer in the Reference group. Use this as a background layer to help designate AW events within the given HUC-12.
6. Another column whose header is highlighted yellow (**Flowlines cross State_Boundary_Hybrid**) indicates HUC-8s whose flowlines cross the Minnesota border. AW events need to be created for those flowlines only within Minnesota (see step 10 below).
7. Since metadata will not be loaded at this time: Select HEM Toolbar > Edit Tools > Options > Options tab.
8. In the Metadata section, ensure *Start Editing starts Metadata Session* checkbox is unchecked. Click Apply and Close button. Save mxd to local directory.
9. Start an edit session and select the *Altered_Watercourse* layer to edit.
10. If NHDFlowlines of the HUC-8 cross the Minnesota border go to [Appendix F](#). Otherwise, select all NHDFlowlines.
11. Set HEM Target layer to Altered_Watercourse then click on the HEM Toolbar: Edit Tools > **Import Selected Flowlines**. Click **OK** button on dialog that appears saying: “Could not find table NHDReachCode_ComID in the database...” AW event features will be created all at once for all NHDFlowlines within the chosen HUC-8.
12. At the end of the process an import report dialog will pop up. Click the **Save to Report** button and save the text file report as *Import.txt* to the local directory that contains your HUC-8. Also click **Close** button. Note: If “Failed to Import Flowlines” > 0 in report, quit edit session without saving and rerun steps 9 – 12. Report any persistent errors to Jim & Susanne.
13. Proceed with steps shown in the flowchart below for each *Altered_Watercourse* event. For examples using Altered Watercourse Criteria see [Appendix A](#) and for examples using No definable channel Criteria [Appendix B](#) and for Impounded Watercourse Criteria see [Appendix C](#).
14. If necessary, an AW event may be split using the **Split Event** tool in the HEM toolbar but note that the MPCA sets a minimum Assessment Unit length for a stream at 150 meters so individual AW events should be this length or longer. Note: AW events that are from different reaches cannot be merged.

NHD Altered Watercourse Event Type Determination Flowchart



Tips

- Concentrate efforts on major, named rivers and streams
- Do easy AW determinations first.
- Don't agonize over individual determinations. If uncertain, give AW event a Low or Medium confidence and move on.
- Use ArcMap shortcuts: Z = zoom in, X = zoom out, C = pan.
- Generally work within the 1:2000 to 1:10,000 scale range
- Set snapping environment to NHDFlowline End & Vertex (and Edge when needed).
- Bookmark those areas that require further study
- Save often!

Confidence Scoring Guidelines

Determining whether a given watercourse is altered, natural, impounded or not defined may require some subjectivity but, hopefully, this will be minimized and most decisions will be based on the objective procedures and criteria given above. Once decided, the analyst then needs to posit his/her level of confidence in that determination. The three confidence values and their descriptions are given below:

- **High Confidence**
Using the procedures and criteria listed above the analyst is certain (or nearly so) that the selected watercourse event is altered, natural or impounded. If questioned, the analyst should be able to defend the criteria and reasoning used to come to his/her determination. This confidence level should involve the least amount of subjectivity by the analyst.
- **Medium Confidence**
Using the procedures and criteria listed above the analyst has a moderate amount of confidence in his/her altered watercourse type stream determination. Some of the criteria used in the determination may be ambiguous or contradictory or involve a certain amount of subjectivity but the analyst should still be reasonably justified in his/her determination.
- **Low Confidence**
Using the procedures and criteria listed above the analyst has a low amount of confidence in his/her altered watercourse type stream determination. This confidence level involves the greatest amount of subjectivity from the analyst and will signal to the AWAT reviewers that the event should be QA/QCd.

NHDFlowline Update Needed

The stream data of NHD was originally captured from USGS 1:24,000 scale topographic maps and updated over time. Although in most areas it is reasonably accurate at representing what's on the ground there are some areas where it is significantly in error due to recent urbanization, ditching/tiling activity or even poor digitization. Because Altered Watercourse events are built on the NHDFlowline data it is prudent to flag those flowlines that are incorrect for future remediation.

The following NHDFlowline Update Types are available on the AW toolbar as a pick-list:

Update Type	Description
None	No update to flowlines needed (default)
Add	Add flowlines that should be near or connected to selected flowline(s)
Delete	Delete selected flowline(s)
Change FType	Change selected flowline(s)' feature type (e.g. Stream/River to Canal/Ditch)
Change Geometry	Change either a flowline(s)' flow direction, length (decrease or increase) or shape (e.g. sinuous to straight)
Other	Any other type of suggested NHD change not in the list above or more than one that is equally applicable. This choice requires a comment added in the Notes field.

Choose the update type that best represents what kind of correction the NHDFlowline data needs even if there is more than one type. Only if there is more than one type that is significantly and equally applicable should the *Other* type be chosen.

Note: Although the NHD update type determination is helpful for potential future NHD editing it is of secondary importance to this project. Therefore, minimal time should be spent on it. This coding merely flags the need for an update; future NHD editors will determine exactly what needs to be done.

Adding Notes

Clicking the *Notes* button on the AW toolbar opens a dialog that allows the analyst to enter comments (up to 255 characters) related to the selected AW events. These can be explanations for choosing the given AW type, confidence or NHDFlowline update type, questions regarding the data or any other pertinent information. Although comments are not required they can be useful for tracking the reasoning process used to make and attribute AW events.

Criteria

Standardized criteria were developed as part of the event type determination methodology to aid the analyst making the determinations and to make the process repeatable. As can be seen on the determination flowchart, each set of yes/no decisions eventually terminate at a specific event type and confidence value. To simplify tracking and analysis of the decision process used for a given **Altered_Watercourse** event each “decision terminator” (rounded rectangle) is given a unique letter that is recorded by the analyst in the *CritLetter* field of the event feature class table (see table below).

In addition, certain decision terminators require additional criteria that are found in the tables Altered Criteria and Impounded Criteria below. Each of these criteria is numbered uniquely and its value is recorded by the analyst into one of three criteria number fields (*CritNum1*, *CritNum2*, and *CritNum3*). The number of these criteria required is determined by the chosen decision terminator. The analyst should enter some value into the criteria fields even if uncertain but use the *Confidence* and *Notes* field to indicate their level of (un)certainty.

Lettered Criteria (Decision Terminator)	
Letter	Description
A	Type = Natural; Confidence ≤ High
B	Type = Altered; Confidence ≤ High
C	Type = Natural; Confidence ≤ Medium
D*	Type = Altered; Confidence = Low
E*	Type = Altered; Confidence ≤ Medium
F*	Type = Altered; Confidence ≤ High
G*	Type = No definable channel; Confidence = High, Medium or Low
H	Type = No definable channel; Confidence ≤ High
I	Type = No definable channel; Confidence ≤ High
J	Type = Impounded; Confidence ≤ High
K	Type = No definable channel; Confidence ≤ Medium
L*	Type = Impounded; Confidence = Low
M*	Type = Impounded; Confidence ≤ Medium
N*	Type = Impounded; Confidence ≤ High
	* These lettered criteria require additional numbered criteria from the Altered, No definable channel or Impounded tables below.

Numbered Criteria

Altered Criteria

Number	Description
1	WC does not exist on prior aerial photography
2	WC feature flows parallel to road or other artificial structure (e.g. levee)
3	WC's sinuosity is significantly decreased from connected WCs
4	WC cuts across old oxbows and meanders
5	WC feature flows across or starts inside dried-up wetland, pond or lake
6	Uniform-colored halo of pixels on imagery is thin, of constant width and parallel to WC
7	WC does not follow DRG stream lines
8	WC crosses DRG contours unnaturally
9	DRG elevation contours straight, close & parallel to WC
11	LiDAR imagery shows WC as straight & narrow or otherwise unnatural shape
12	Associated MPCA Bio Site shows stream as altered
13	Associated DRG stream or GNIS feature labeled <i>County</i> or <i>Judicial Ditch</i>
14	Associated DNR 24k Stream feature's type is <i>Artificial</i> or nearby type is <i>Superseded Natural Channel</i>
15	Associated GNIS feature's FEATURE_CL = <i>canal</i>
16	Associated NWI feature's SPEC_MOD is any type but blank or b (beaver)
17	Associated PWI Streams feature's PWI_Flag = 2
18	WC connected or adjacent to artificial WB (e.g. Sewage Treatment Pond)

No definable channel Criteria

Number	Description
21	WC crossed by row crops or tillage*
22	WC shallow and indistinct or does not exist on LiDAR imagery
23	No associated DRG stream exists
24	Associated NHD Flowline Type = Pipeline
25	Surrounding terrain recently urbanized, mined or otherwise developed
26	Wetland area with indistinct/indefinite WC
27	WC channel dry in most years and frequently grassy; wide and shallow in LiDAR imagery

Impounded Criteria

Number	Description
31	WB does not exist or is significantly different in prior aerial photography
32	WB overlies DRG land contours (but not due to registration errors)
33	WB has associated active dam in DNR dams shapefile
34	Associated MPCA Bio Site shows impoundment
35	Associated DNR 100K Lakes and Rivers feature's USCLASS = 412
36	Associated GNIS feature's FEATURE_CL = <i>dam</i> or <i>reservoir</i>
37	Associated NWI feature's SPEC_MOD is <i>h</i> (Diked/Impounded) or <i>x</i> (Excavated) and <u>not</u> <i>b</i> (Beaver)
38	WB has straight shoreline perpendicular to its outlet stream
39	Associated DRG WB is labeled with words <i>Pool</i> , <i>Normal Level</i> , <i>Reservoir</i> , <i>Spillway</i> or <i>Tailings Pond</i>

Note: WC and WB stand for Watercourse and Waterbody respectively.

Corrections

Complete the following process if you've been notified by MnGeo project leadership that a HUC-8 on which you completed initial edits needs correction.

1. Enter the current date in the **Date Started** field of the **Correction Edits** section of the *Status* spreadsheet.
2. Unzip the given HUC-8 zipfile from ...\\HUC-8s\initial to its own corrections directory on your local drive.
3. Find the MPCA review shapefile for the given HUC-8 (e.g. 04010102.shp) in ...\\HUC-8s\reviews and copy it to your local corrections directory.

The following table shows the required fields in the review shapefile. All other fields may be ignored.

Field Name	Type	Description
Reviewer	Text	Initials of MPCA reviewer
Criteria	Text	Suggested criteria letter
Critnum_1	Long	Suggested criteria number 1 (if necessary)
Critnum_2	Long	Suggested criteria number 2 (if necessary)
Critnum_3	Long	Suggested criteria number 3 (if necessary)
Comments	Text	Explanation by reviewer (if necessary)
HUC_8	Text	8-digit USGS Hydrologic Unit Code

4. To this MPCA review shapefile add two new fields called **Agree_type** (text, Length=1) and **Response** (text, Length=150).
5. If it's missing, add and calculate HUC_8 field to the given HUC-8 number.
6. In ArcMap, load the HUC-8 data and review shapefile from your local corrections directory as well as the Reference.lyr file from ...\\layer_files.
7. Zoom to each record in the review shapefile and look at its suggested changes.
8. If you agree with the suggested event type only (as implied by the suggested criteria letter or comments) put a 'Y' in the record's *Agree* field and make the necessary changes to the associated AW event. Note: This applies even if you agree with the suggested type but disagree with the suggested criteria letter or numbers (e.g. H and I both imply *No definable channel* but I is within a waterbody and H is not). In these cases, put a 'Y' in the record's *Agree* field and the description of your disagreement in the *Response* field (e.g. "should be I, not H").
9. If you disagree with the suggested event type put an 'N' in the *Agree* field and the reason for your disagreement in the *Response* field (e.g. "see 2010 FSA"). These disagreements will be addressed by MnGeo and MPCA in the future.
10. When corrections are completed, run the QA/QC processes (pp. 17-20), zip the contents of your local corrections folder (using file format: AW<HUC-8>.zip e.g. AW07010101.zip) and copy to ...\\HUC-8s\corrected.
11. Enter data for the **Date Completed**, **Hours to Complete** and **Any disagreements with MPCA comments?** fields under the **Correction Edits** section in the *Status* spreadsheet.

12. Email MnGeo project leadership that you've completed corrections of the given HUC-8.

Final Edits



This describes the process of how AW type, confidence or criteria code disputes between MnGeo's analysts and MPCA's reviewers will be resolved. Generally they will be resolved by MnGeo's and MPCA's project leadership with potential assistance from the broader AWAT (AW Assessment Team). The actual final editing of the data will be done by MnGeo analysts.

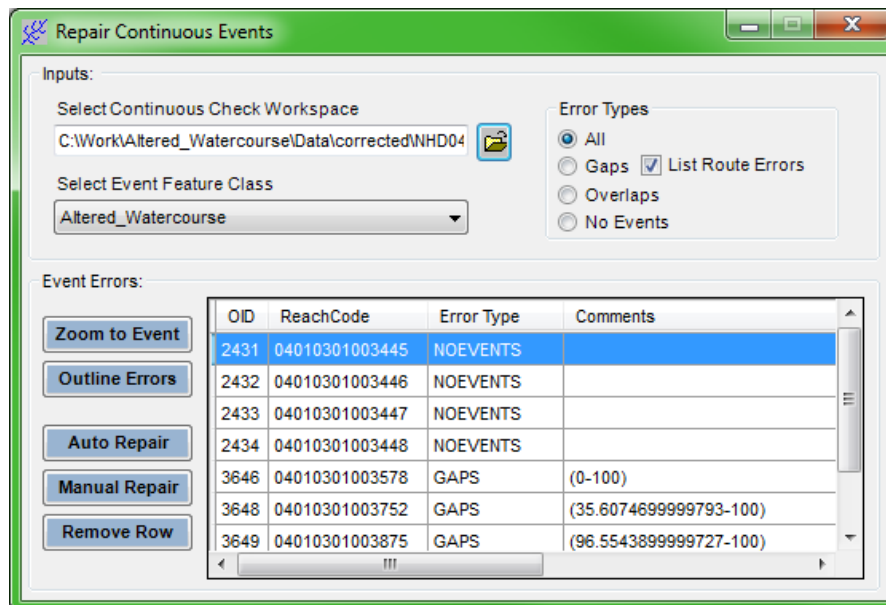
1. Disputed records are designated by **Agree_Type** field = 'N' in the NHDDIST.AW_MPCA_Reviews feature class of the SDE NHDDIST.AWAT dataset.
2. Each disputed AW event is looked at in ArcMap with suitable reference layers visible. The respective reviewer comments and analyst responses are also considered.
3. Once a consensus on the correct AW type, confidence and criteria codes has been reached enter the information into the NHDDIST.AW_MPCA_Reviews feature class' **Decision** field.
4. If the decision requires changes to the given HUC-8 events (i.e. disagrees with MnGeo Analyst's Response) set **Final_Edit** field = 'Y'
Otherwise, set **Final_Edit** field = 'N'
5. MnGeo analyst(s) are then tasked with completing necessary Final Edits:
 - a. Copy corrected version of HUC-8 to local machine
 - b. Load NHDDIST.AWAT/NHDDIST.AW_MPCA_Reviews feature class
 - c. For given HUC-8, find those records where [Final_Edit]='Y'
 - d. Edit AW events per NHDDIST.AW_MPCA_Reviews.Decision field
 - e. When done with edits complete HUC-8 Wrap-Up procedure as normal (pp. 17-20).
 - f. The Post-Edit Process will then be performed by designated staff.

HUC-8 Wrap-Up

Once AW event edits are complete for a given HUC-8 the analyst needs to perform their own basic geographic and attribute QA/QC of the AW event data before it is passed on to the AWAT reviewers.


Geographic QA/QC

1. In ArcCatalog, run the **Check Continuous Events** tool  found on the HEM toolbar. (Running the tool in ArcMap may result in errors that are not apparent and so should be avoided).
 - a. The tool outputs both a personal geodatabase (.mdb) and text file error report with the file name format of HEMContEvtQC_<YYMMDDHHNNSS>². First, open the text file error report to check if any continuity errors were found. If none are found, skip remaining steps and proceed with Attribute QA/QC (p. 19).
 - b. If HUC-8 crosses the state boundary then go to **Appendix G**.
2. In ArcMap, load mapfile of given HUC-8 created for editing, if necessary.
3. Start editing on the Altered_Watercourse layer. On HEM toolbar, click Edit Tools > Snap Environment and make sure at least the Altered Watercourse *End* box is checked.
4. Click Edit Tools > Repair Continuous Events tool  on the HEM toolbar. The following dialog will appear:



² Second half of filename is timestamp where: YY = 2-digit year, MM = 2-digit month, DD = 2-digit day, HH = 2-digit hour, NN = 2-digit minute and SS = 2-digit second (e.g. HEMContEvtQC_120214043104)

5. Enter the error report geodatabase created in step 1 into the **Select Continuous Check Workspace** control. Pick *Altered_Watercourse* under **Select Event Feature Class** if necessary.
6. Select a record in this dialog.
7. Click the **Zoom to Event** and **Outline Errors** buttons to visualize the error on the map.
8. The Error Types and how to fix them are given below. (All buttons described pertain to the **Repair Continuous Events** dialog unless otherwise noted.)
 - a. NO EVENTS
 - i. If **Auto Repair** button is enabled click it. If not, use **Create Line Event** tool on HEM toolbar to create event(s).
 - ii. Add the correct AW attributes to the new event(s).
 - iii. If you had to use the **Create Line Event** tool to create the new event then click the **Remove Row** button.
 - b. GAPS
 - i. If gap error is not within Minnesota click **Remove Row** button. Skip remaining steps under GAPS.
 - ii. If **Auto Repair** button is enabled click it. This will create a new event without gaps overlying the original event.
 - 1) First record AW attributes of the original event. Then use **Delete Event** tool on HEM toolbar to select both new and original events.
 - 2) In the **Select Events** dialog that pops up select only the original event(s) with gaps (BEG MEAS and END MEAS = 0) and click the **Delete** button.
 - iii. If **Auto Repair** button is not enabled you will have to create a new event using the Create Line Event tool on the HEM toolbar.
 - 1) First record AW attributes of the original event. Then delete the errant AW event using the **Delete Event** tool on the HEM toolbar.
 - 2) Use **Create Line Event** tool to add a new AW event.
 - 3) Click the **Remove Row** button.
 - iv. Add the recorded AW attributes to the new event(s).
 - c. OVERLAPS
 - i. If overlap error is not within Minnesota click **Remove Row** button. Skip remaining steps under OVERLAPS.
 - ii. Click **Manual Repair** button.

- iii. Select any candidate AW event in the update dialog. (It does not matter which one, because of a bug the candidate dialog does not actually select any event.)
 - iv. Click the  button on the HEM toolbar and select the one overlapping event that is either:
 - 1) the most incorrect (if you can tell)
 - 2) the shortest
 - v. Click to set the new beginning point of the event
 - vi. Shift+click to set the new ending point of the event
- d. Any error where **Comments** = “Underlying Route Error”: click **Remove Row** button. (These errors cannot be fixed at this time.)
9. Repeat steps 6 - 8 for every record in the **Repair Continuous Events** dialog. If unable to fix an error(s) using the **Repair Continuous Events** tool calculate Repaired field to 2 and notify Student Team Leader and cc: Susanne and Jim (see step 5, Closeout section).
10. When done making repairs, make sure that all fixed records in the Altered_Watercourse_err table have their Repaired field set to 1 or 2. (There is no need to rerun the **Check Continuous Events** tool once all fixes have been made.)

Attribute QA/QC

Once the geographic QA/QC is complete for a given HUC-8 the analyst should then run the Attribute QA/QC python script *AW Attribute Check*. This script checks the **integrity** (i.e. completeness and consistency) of the AW attribute data. It does not look at the **correctness** of the data as that is done by AWAT reviewers once the data is released.

Running the Script

1. Open *Altered Watercourse Tools* in ArcToolbox
2. Double-click **AW Attribute Checker** script
3. Input path to the personal geodatabase containing the given Altered_Watercourse.
4. Unless a critical (showstopper) error occurs that prevents the script from continuing (e.g. missing Altered_Watercourse table), errors will be entered into the **AW_Attribute_Errors** table created within the given HUC-8 geodatabase.

This table has the following format:

Field Name	Field Type	Field Description
ID	Text	ObjectID from Altered_Watercourse
Error Number	Short Integer	Error ID number
Error Description	Text	Definition of error produced

5. Relate the ID field from AW_Attribute_Errors to the ObjectID field of Altered_Watercourse and use to locate and fix the given errors.

6. For descriptions of the error (test) numbers and types see [Appendix G](#).
7. If fixes were needed, rename **AW_Attribute_Errors** by appending **2, 3...**
8. Rerun script until no more errors are found.

Note: If any geographic changes were necessary to fix attribute errors then rerun the **Geographic QA/QC** process (pp. 17-19) before rerunning **Attribute QA/QC**.

Closeout

1. Compress at least the following files into a single zip file named: AW<HUC-8>.zip (e.g. AW07010101.zip):
 - a. Personal geodatabase containing Altered_Watercourse (.mdb) and latest AW_Attribute_Errors table (without errors)
 - b. Latest existing Import Log files (*Import.txt* - should be without import errors)
 - c. Latest continuity check geodatabase (HEMContEvtQC_<YMMDDHHNNSS>) which contains the Altered_Watercourse_err table (Repaired = 1 or 2 for every existing record)
 - d. Review shapefile created by MPCA and annotated by the analyst (if edits are corrections)
2. If completing initial edits, copy zip file to ...\\HUC-8s\\initial
3. If completing correction edits, copy zip file to ...\\HUC-8s\\corrected
4. If completing final edits, copy zip file to ...\\HUC-8s\\final
5. Update *Status* spreadsheet accordingly (see [Status Tracking](#) section)
6. Email MnGeo's project leadership when done and notify them if unable to fix any errors using the Repair Continuous Events tool.

Post-Edit Process

This process will be performed by MnGeo's project leadership when emailed by MPCA or an analyst regarding an edit or review completion. Each subsection below should be performed singly by itself unless indicated otherwise.

If emailed by MPCA

Review shapefile received from MPCA

1. In the *Initial Edits* section of the *Status spreadsheet* for the given HUC-8:
 - a. Enter date received in **Date Review Shapefile Received from MPCA** column
 - b. Select **Corrections Needed** in the **MPCA Check Status** column
2. Unzip shapefile(s) to ...\\HUC-8s\\reviews directory
3. Email appropriate analyst that review shapefile has been received

Notification that no corrections needed received from MPCA

1. If notified by MPCA that no corrections are needed for a given HUC-8 select **No corrections needed** in **MPCA Check Status** column of the **Status** spreadsheet
2. Copy HUC-8 zip file from ...\\HUC-8s\\initial to ...\\HUC-8s\\final
3. Email appropriate analyst that no corrections are needed for the given HUC-8
4. Proceed with *For Final Edits* subsection below

If emailed by Analyst

For All Edits

1. For the given HUC-8 zip file from ...\\HUC-8s\\initial, ...\\HUC-8s\\corrected or ...\\HUC-8s\\final verify :
 - a. That it contains all the files listed in step 1 of the Closeout section.
 - b. That the **AW_Attribute_Errors** table in the AW personal geodatabase contains no errors.
 - c. That the number of **Failed to Import Flowlines** equals 0 in the latest *Import.txt* Log file.
 - d. That **Altered_Watercourse_err.Repaired** = 1 or 2 for every existing record unless otherwise notified by analyst (step 5 of Closeout section)
2. In the appropriate status column (e.g. **Post-Initial Status, Post-Correction Status** or **Post-Final Status**) of the **Status** spreadsheet for the given HUC-8:
 - a. Select **Hold – Fixes needed** if any criteria from step 1 are not correct and notify analyst. Do not proceed until resolved.
 - b. Select **OK** if all criteria are correct and proceed with appropriate subsection below.

For Initial Edits

1. In the NHDDIST.AWAT SDE dataset for the given HUC-8 load the **Altered_Watercourse** feature class(es) into NHDDIST.AW_INITIAL *
2. In the *Initial Edits* section of the **Status** spreadsheet for the given HUC-8:
 - a. Enter today's date into the **Date Uploaded to WMS (AW_INITIAL)** column
 - b. Verify that the **Date Started, Date Completed** and **Hours to Complete** columns were populated by the analyst. (If not, get info from analyst.)
 - c. Set **MPCA Check Status** column to **Pending**
3. Email MnGeo's and MPCA's project leadership the name and HUC number of the HUC-8 uploaded to AW_INITIAL.

For Correction Edits

* All target fields must have matching source fields except for **ComID** and **FeatureCom** which may or may not.

1. In the NHDDIST.AWAT SDE dataset for the given HUC-8:
 - a. Verify that the MPCA review shapefile has populated **Agree_Type**, **Response** and **HUC_8** fields.
 - b. If not, reset **Post-Correction Status** column in the *Correction Edits* section of the *Status* spreadsheet to **Hold – Fixes needed** and notify analyst. Do not proceed until resolved.
 - c. Load Altered_Watercourse feature class into NHDDIST.AW_CORRECTED*
 - d. Load review shapefile for given HUC-8 into NHDDIST.AW_MPCA_Reviews Note: Target fields DECISION, MNGEO_ID and FINAL_EDIT will not have matching Source fields.
 - e. For records just loaded into NHDDIST.AW_MPCA_Reviews (i.e. MNGEO_ID is NULL) calculate MNGEO_ID field = OBJECTID field
 - f. Calculate AW_MASK.CORRECTED field = 'YES' for the given HUC-8
2. In the *Correction Edits* section of the *Status* spreadsheet for the given HUC-8(s):
 - a. Enter today's date into the **Date Uploaded to WMS (AW_CORRECTED)** column
 - b. Verify that analyst populated the **Date Started**, **Date Completed**, **Hours to Complete** and **Any disagreements with MPCA comments?** columns (If not, get info from analyst.)
3. Email MnGeo's and MPCA's project leadership the name and HUC number of the HUC-8 uploaded to AW_CORRECTED
4. Email shapefile of disagreements from AW_MPCA_Reviews to project leadership at MPCA.

For Final Edits

1. Verify analyst completed all Final Edits by ensuring every record in the review shapefile has Completed = 'Y' where Final_Edit = 'Y'
2. Load Altered_Watercourse for the given HUC-8 into NHDDIST.AW_FINAL* in the NHDDIST.AWAT SDE dataset.
3. In the *Final Edits* section of the *Status* spreadsheet for the given HUC-8(s):
 - a. Enter today's date into the **Date Uploaded to WMS (AW_FINAL)** column
 - b. Verify that the **Date Completed** and **Final Editor** columns were populated by the analyst. (If not, get info from analyst.)

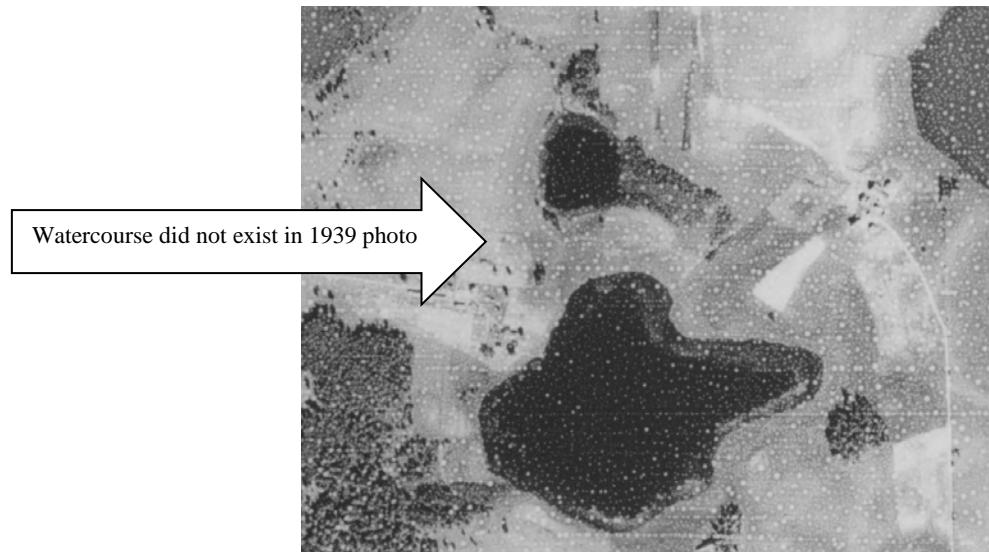
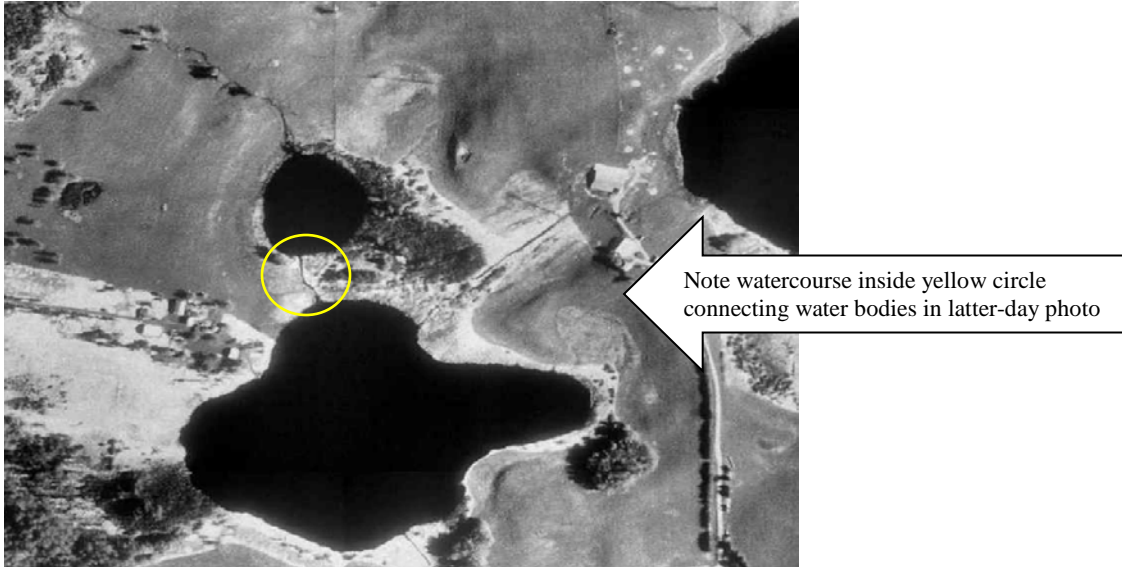
* All target fields must have matching source fields except for **ComID** and **FeatureCom** which may or may not.

Appendix A: Examples of *Altered* Watercourse Criteria

The following are examples of the criteria used for designating a given event as an *Altered* watercourse.

1. Watercourse does not exist on prior aerial photography

Unless there has been some kind of catastrophic event (e.g. earthquake, landslide) nature usually takes thousands of years to create a watercourse. Those created within a few decades are most likely artificial.



2. Watercourse feature flows parallel to road or other artificial structure (e.g. levee)

This indicates that the stream was modified to permit construction of artificial structure.



3. Watercourse's sinuosity is significantly decreased from connected watercourses

Because there are no straight lines in nature, altered streams are rarely as sinuous (i.e. have natural appearing curves) as natural streams.



4. Watercourse cuts across old oxbows and meanders

An altered portion of a natural stream often cuts directly across the former meanders and oxbows of the original channel in an unnatural (i.e. straightened and direct) way.



But, be careful channel is not a natural cut-off of a meander.

These will likely be shorter and more natural appearing than an artificial channel and, since they are by definition not dredged, may show development of their own meanders over time in the photos.

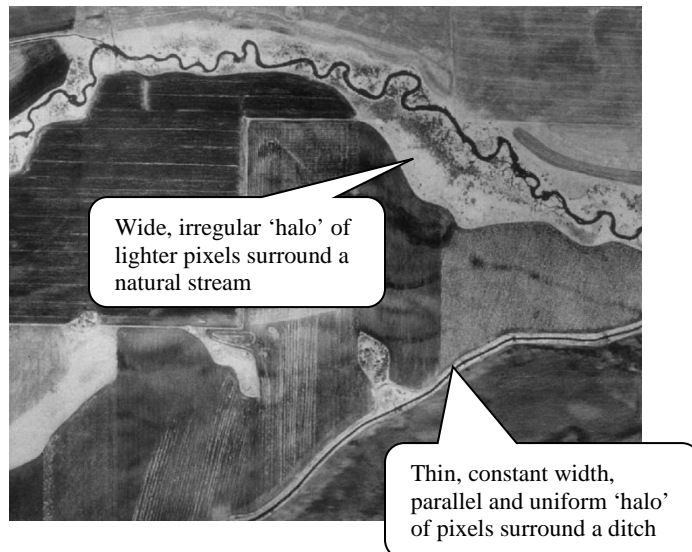


5. Watercourse feature flows across or starts inside dried-up wetland, pond, or lake
Ditches and altered streams are often used to drain old wetlands or water bodies.



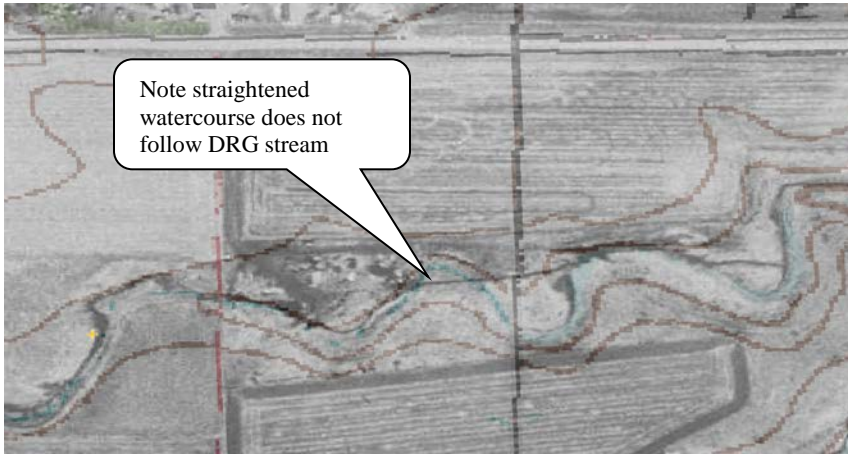
6. Uniform-colored halo of pixels on imagery is thin, of constant width and parallel to watercourse

The photographic imagery sometimes displays a watercourse with a 'halo' of uniform-colored pixels around the channel of dark-colored ones. The relative shape and width of these halos may be used to help determine if the watercourse is natural or altered. Halos that are thin, parallel to and the same shape as the watercourse itself are probably around an altered stream. If a natural watercourse has such a halo, it tends to be wider, less distinct in color from adjacent areas and more irregular in shape.



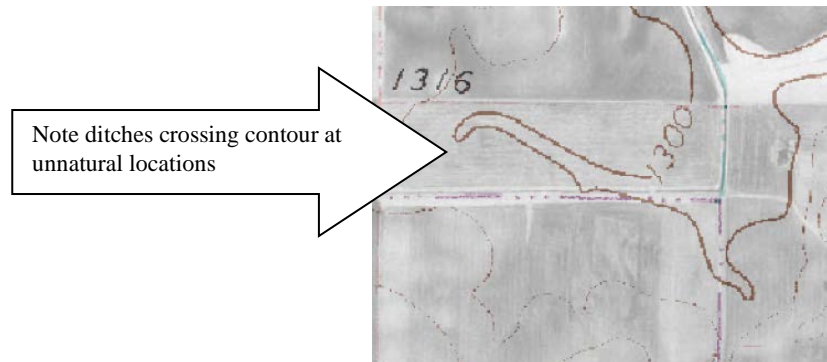
7. Watercourse does not follow DRG stream lines

Streams that have been altered since the DRG was created will often not follow the original DRG stream lines.



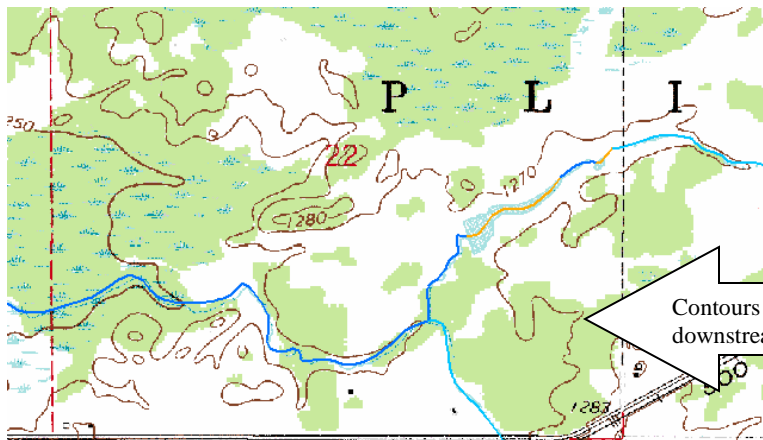
8. Watercourse crosses DRG contours unnaturally

Altered streams (especially those newer than the DRG) may cut across elevation contours at unnatural places or even appear to go uphill. Natural streams tend to cross at the V-shaped notches of contours and, of course, travel only downhill.



9. DRG elevation contours straight, close & parallel to watercourse

Many ditch/canals have close-in, straight elevation contours on the DRG that stay with them much of their length.



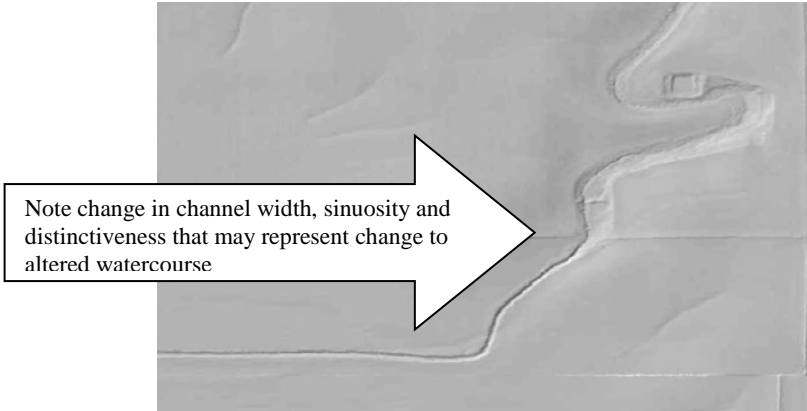
Contours that cross natural streams tend to move farther apart and become more irregular in shape as they go downstream.

Contours get wider and more irregular downstream after crossing natural streams

Note: Criteria #10 was removed in an earlier version of the methodology document.

11. LiDAR imagery shows watercourse as straight & narrow or otherwise unnatural shape

Because of the precise nature of LiDAR hillshade data it can sometimes help differentiate an altered from a natural stream by revealing unnatural characteristics not clearly visible in the aerial photography.



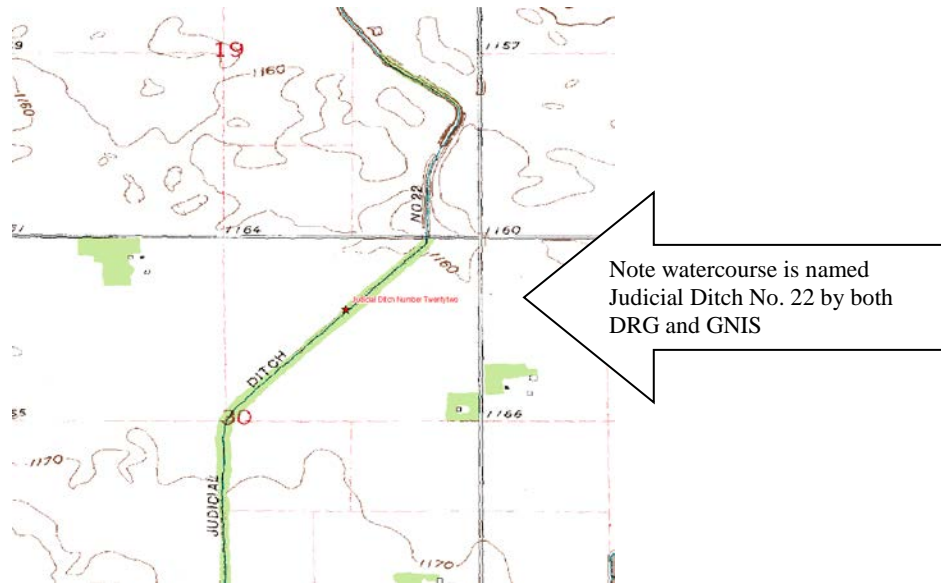
12. Associated MPCA Bio Site shows stream as altered

These lateral photos taken at ground level may give some clues as to whether a stream has been altered or not.



13. Associated DRG stream or GNIS feature labeled *County* or *Judicial Ditch*

The ditch labels in DRG or GNIS data are but one more clue that a given watercourse is altered.



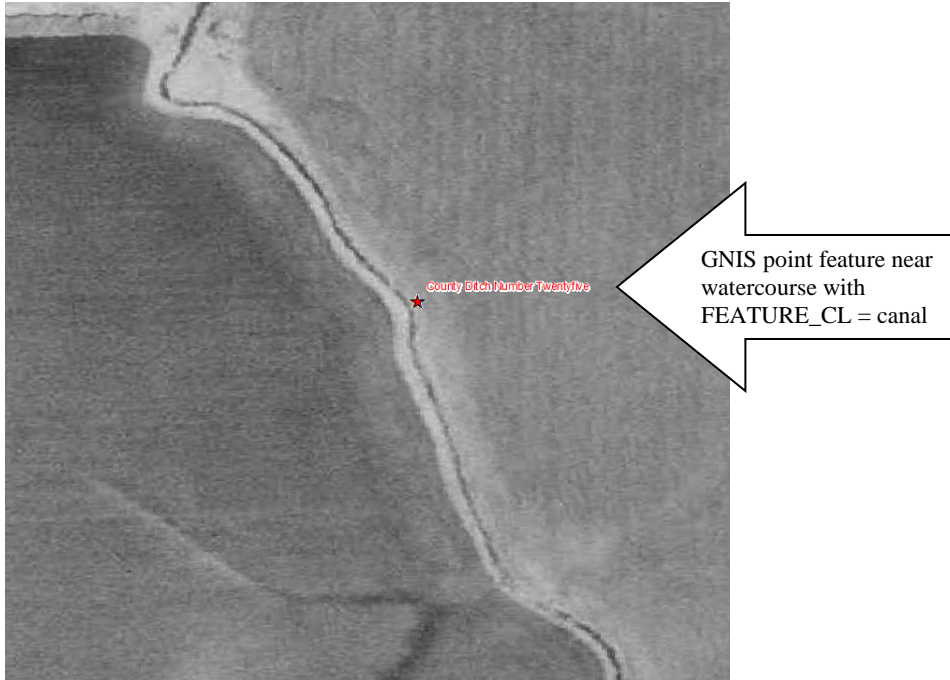
14. Associated DNR 24k Stream feature's type is *Artificial* or nearby type is *Superceded Natural Channel*

Although the DNR's definition of Artificial is not equivalent to Altered for this project, it may nonetheless indicate a stream has been altered. Also, a Superceded Natural Channel is a natural stream that has been replaced with an overlying or nearby artificial channel that may be Altered.



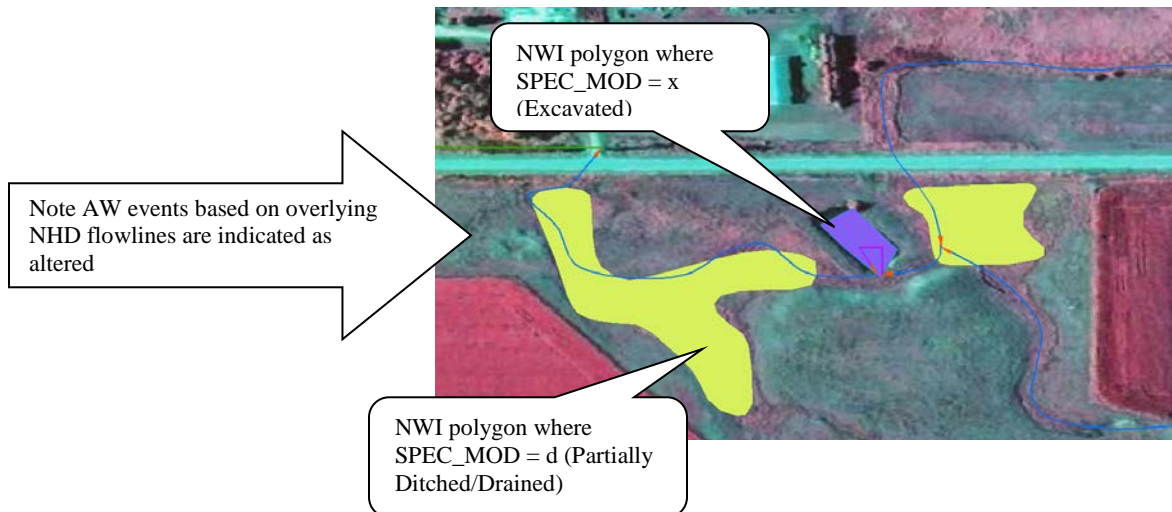
15. Associated GNIS feature's FEATURE_CL = canal

The Geographic Names Information System (GNIS) of the USGS includes hydrographic points of different classes (i.e. FEATURE_CL). The one named canal indicates an artificial channel.



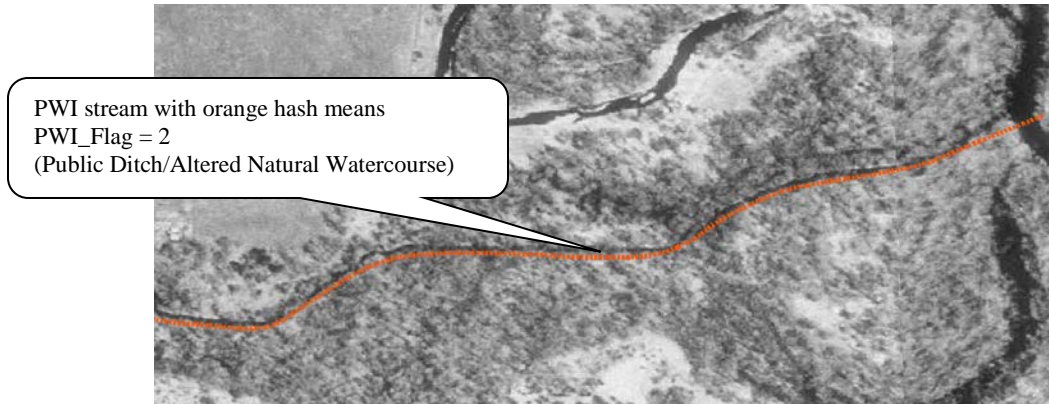
16. Associated NWI feature's SPEC_MOD is any type but blank or b (Beaver)

The National Wetlands Inventory (NWI) polygons may have values in their Special Modifier (SPEC_MOD) fields that indicate an overlying or nearby stream has been altered. These are: d = Partially Drained/Ditched, f = Farmed, h = Diked/Impounded, r = Artificial Substrate, s = Spoil and x = Excavated. Where SPEC_MOD = b means Beaver influenced area and therefore does not indicate an altered watercourse.



17. Associated PWI Streams feature's PWI_Flag = 2

Public Waters Inventory (PWI) streams from the DNR may have PWI_Flag = 2 which designates the stream as *Public Ditch/Altered Natural Watercourse*. Although not equivalent to Altered in this project's context it nonetheless may indicate the stream is Altered.



18. Watercourse connected or adjacent to artificial Waterbody (e.g. Sewage Treatment Pond)



Watercourses flowing into and out of man-made reservoirs are usually altered (see watercourse pointed to by white arrows in photo). Reservoirs may be found using the FType of the NHDWaterbody layer, labeled as such on the DRG or seen on the imagery as a darker polygon with a regular (e.g. rectangle or circle) or otherwise non-natural shape.

Appendix B: Examples of *No definable channel* Watercourse Criteria

The following are examples of the criteria used for designating a given event as a *No definable channel* (i.e. channel does not exist or is otherwise unsuitable for MPCA purposes).

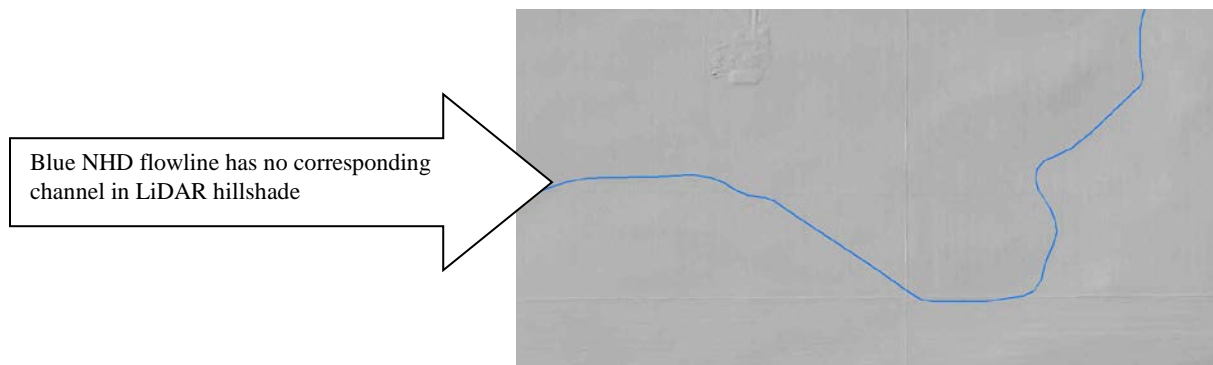
21. Watercourse crossed by row crops or other tillage

A channel that has been planted over or tilled is likely too small or indistinct.



22. In non-wetland areas, watercourse indistinct or does not exist on LiDAR imagery

Except in wetland areas, LiDAR is very good at penetrating vegetative cover (i.e. tree canopies) and showing natural stream and ditch channels even when they are not visible in aerial photography. Therefore, if a watercourse channel (in a non-wetland area) is not clearly visible on LiDAR hillshade imagery then it likely doesn't exist or is too small for MPCA purposes.

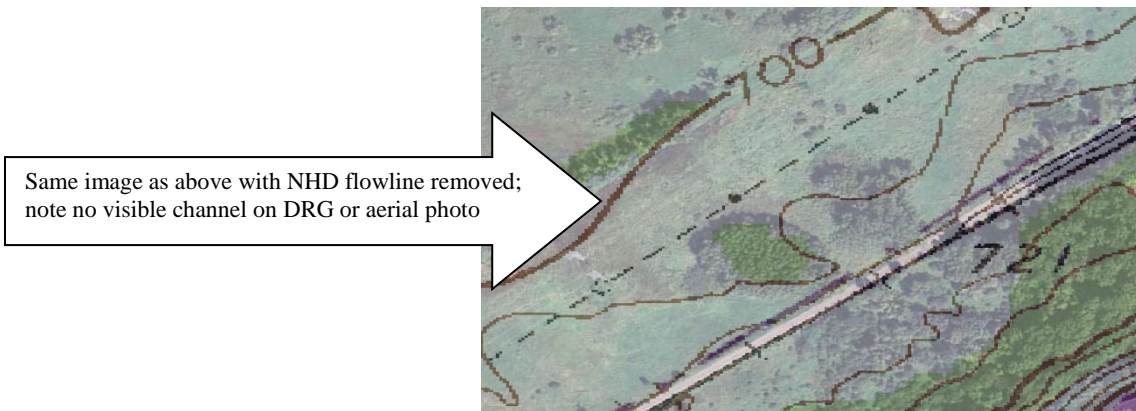


23. No associated DRG stream exists

An NHD flowline (on which AW events are built) that does not have an associated Digital Raster Graphic (DRG) stream line is either: a new, likely Altered watercourse or a mistake. If the aerial imagery (including LiDAR hillshade) clearly shows a channel then criteria #7 is satisfied (Watercourse does not follow DRG stream lines) and the watercourse will be considered Altered. However, if the aerial imagery does not clearly show a channel then this criteria (#23) is satisfied and the watercourse is considered *No definable channel*.



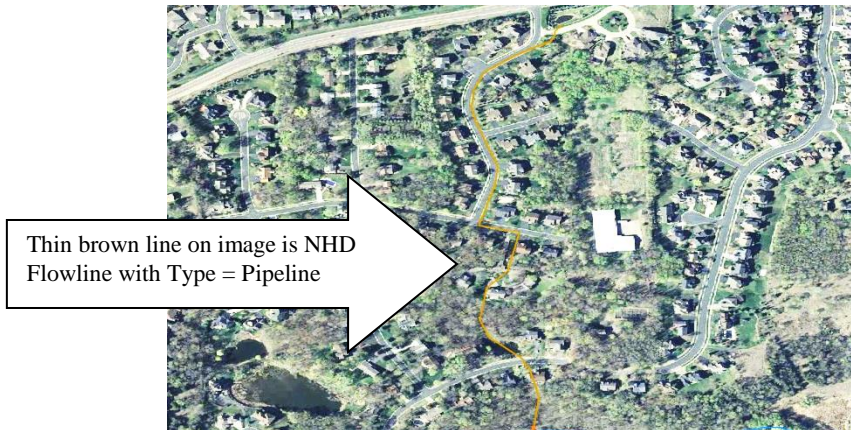
Note thin blue NHD flowline overlying DRG & aerial photo



Same image as above with NHD flowline removed; note no visible channel on DRG or aerial photo

24. Associated NHD Flowline Type = Pipeline

NHD Flowlines designated as Pipelines are generally water supply conveyance or storm water features that are underground and therefore not visible.



25. Surrounding terrain recently urbanized, mined or otherwise developed

The digitization of the NHD flowlines may have preceded development in an area and therefore not represent the current state of hydrography. In these cases, the flowlines and consequently the AW events built upon them are obsolete.



26. Wetland area with indistinct/indefinite watercourse

Water may flow through a wetland area in a very wide, indistinct path that is not visible on aerial imagery or LiDAR hillshade.



Note blue NHD flowline running through wetland area on aerial photo



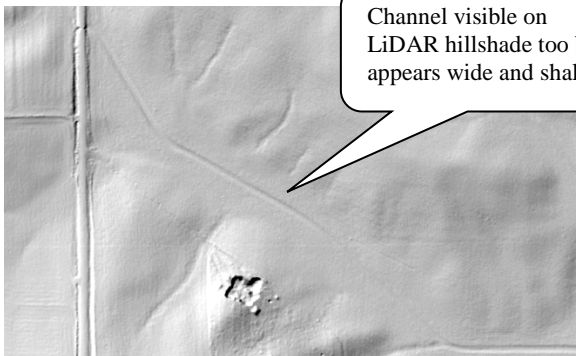
Same area with flowline removed; note no visible channel

27. Watercourse channel dry in most years and frequently grassy; wide and shallow in LiDAR imagery

Sometimes channels that are clearly visible on aerial imagery and LiDAR hillshade are still not suitable for MPCA's purposes. These are wide, grassy channels frequently found in farm country.



Note distinct but grassy channel in farmed area



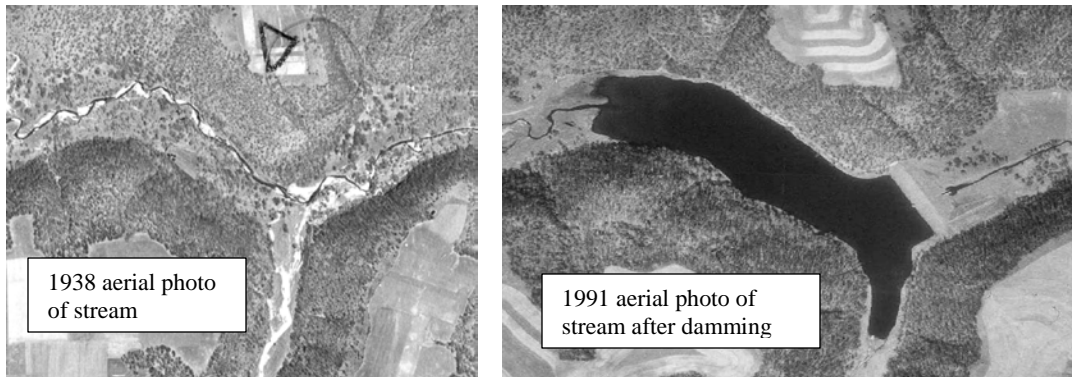
Channel visible on LiDAR hillshade too but appears wide and shallow

Appendix C: Examples of Impounded Watercourse Criteria

The following are examples of the criteria used for designating a given event as an *Impounded* watercourse. For this project, Impoundments are water bodies formed from the artificial damming of a stream and do not include beaver ponds.

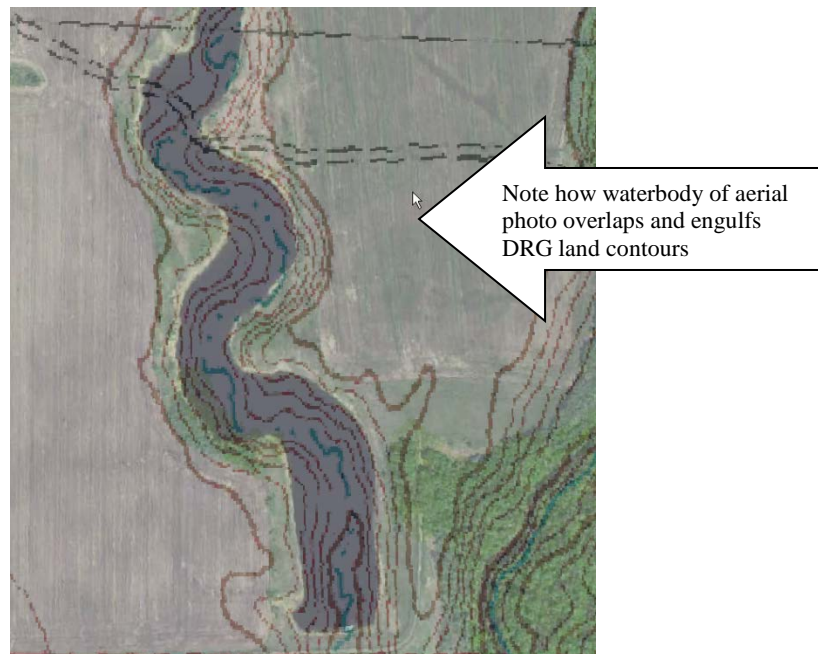
31. Waterbody does not exist or is significantly different in prior aerial photography

Because nature usually takes thousands of years to create a water body one that is formed over only a few years or decades may indicate that it is an impoundment.



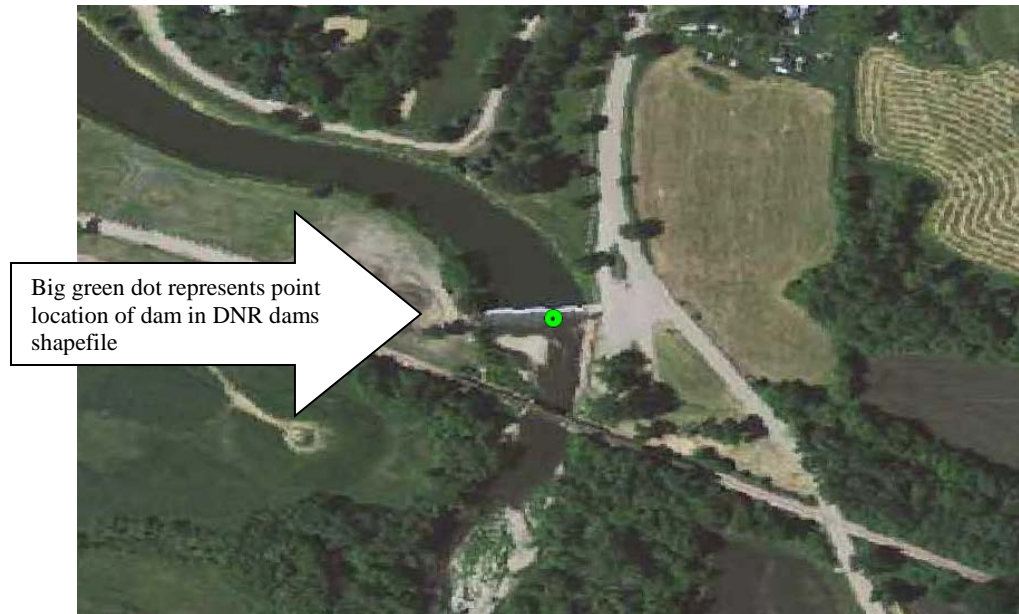
32. Waterbody overlies DRG land contours (but not due to registration errors)

If a waterbody succeeds and overlies DRG land contours then it may be impounded.



33. Waterbody has associated active dam in DNR dam shapefile

The DNR dam shapefile comes from the DNR Dam Safety group and is the most accurate vector point data of Minnesota dams available.



34. Associated MPCA Bio Site shows impoundment

Lateral photos taken at ground level at these sites may indicate the respective water body is an impoundment.



Note: Criteria #35 was removed in an earlier version of the methodology document.

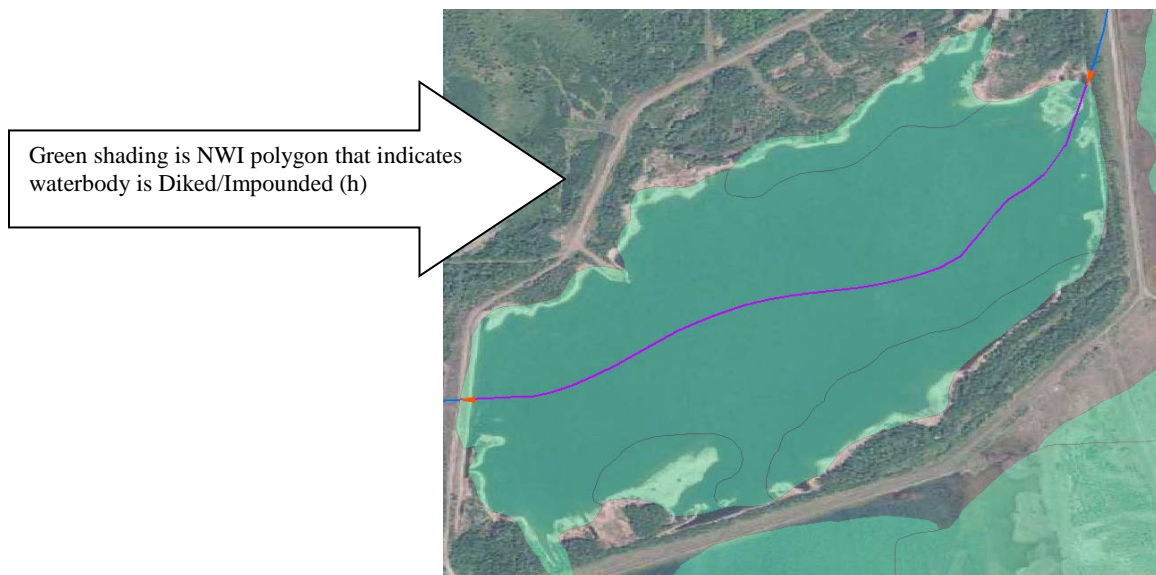
36. Associated GNIS feature's FEATURE_CL = dam or reservoir

The Geographic Names Information System (GNIS) data from USGS includes points for hydrographic features such as dams or reservoirs (impoundments).



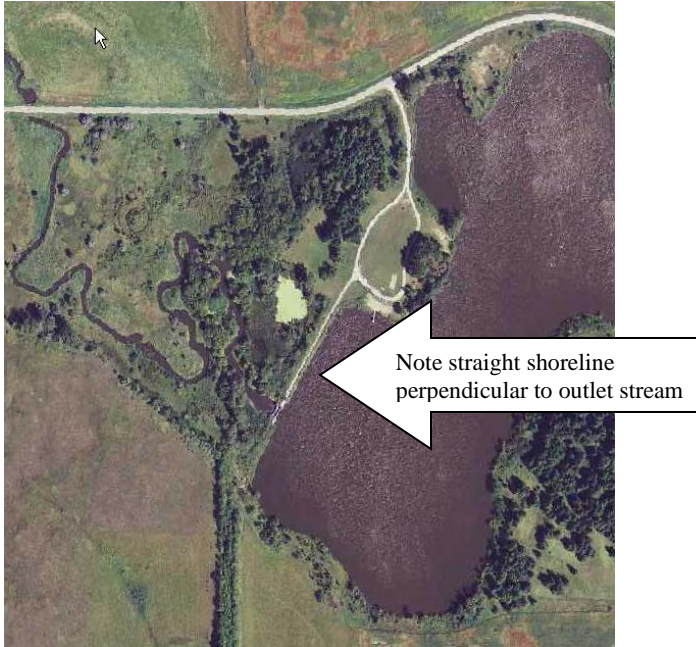
37. Associated NWI feature's SPEC_MOD is h (Diked/Impounded) or x (Excavated and NOT b (Beaver))

If the Special Modifier fields (SPEC_MOD) in the National Wetlands Inventory (NWI) dataset indicate that an area is Diked/Impounded (h) or Excavated (x) then the resulting water body may be impounded.



38. Waterbody has straight shoreline perpendicular to its outlet stream

A straight embankment of a water body at a right angle to its outlet stream is a clear indicator of a dam and impoundment.



39. Associated DRG WB is labeled with words Pool, Normal Level, Reservoir, Spillway, or Tailings Pond

These terms often indicate a given water body is impounded.



Appendix D: Methodology Issues & Clarifications

Below are the 4 most significant issues encountered during the project. In some situations there was disagreement between MnGeo and MPCA and in others just a need for further clarity regarding the methodology. All of them were eventually resolved.

Stream Sampleability

The Minnesota Pollution Control Agency's (MPCA) Biological Monitoring Program needs to determine the location of stream monitoring sites for the purpose of assessing water quality and developing biological criteria. One of their primary considerations is whether a given site is *sampleable* or not. That is, 1) whether or not the respective stream has a clearly defined channel 2) contains water 3) that is not impounded and 4) whether or not the given site is accessible from both safety and legal standpoints.³

The first and third of these criteria are the primary functions of the Altered Watercourse Project which denotes whether given channels represented by NHD flowlines actually exist on the aerial imagery as well as whether they are Altered, Natural or Impounded. During the HUC-12 QA/QC phase of this project it was discussed if the second criterion listed above (i.e. sufficient flow) could also be determined using the available data, staff and other resources. (The fourth criterion was not considered for this project.)

However, it was decided not to include this criterion. Determining whether or not a given stream has sufficient flow for sampling from aerial photographs was found to be very difficult without introducing unacceptable levels of subjectivity. According to the *Reconnaissance Procedures* of the Biological Monitoring Program, to be sampleable a stream must either flow continuously throughout the year or at least 50% of the stream sampling reach must contain water.⁴ The aerial photography was found to be of insufficient resolution and quality to determine this conclusively in most smaller streams (including drainage ditches). Also, even if stream flow was clearly visible in a given year, the next or past years of photography may not be as clear or show a different result. In the end, the *sampleability* of a given stream site was decided to best be the province of field staff.

³ *Reconnaissance Procedures for Initial Visit to Stream Monitoring Sites*, MPCA: Biological Monitoring Program, pp. 4-5.

⁴ *Ibid*, p. 4.

Modified Ditch/Stream Issue (*Is v. Should Be Methods*)

These were cases where a stream or ditch had artificial modifications visible in the aerial imagery but which were not represented correctly in the NHD flowline network. The question was how to handle them. The discussion about this issue eventually included the wider AWAT group where it was resolved.

The two different methods of addressing this issue

- **Should Be** method (originally used by MnGeo): Assign an AW type of *Altered* to the modified stream (with a NHD Update of *Change Geometry*) to signal that NHD should be changed to match changes in the aerial imagery.
- **Is** method (preferred by MPCA): Assign an AW type of *No definable channel* to the modified stream to indicate that NHD is currently non-existent and incorrect versus changes in the aerial imagery.

Example: Line *A* represents existing NHD flowline ditch which has been replaced by actual ditch (Line *B*)



- **Should Be** method – *A* is given *Altered* type (and NHD Update of *Change Geometry*) so that it can approximately represent the new correct ditch location at *B*.
- **Is** method – *A* is given *No definable channel* (and NHD Update of *Change Geometry*) type since a channel no longer exists there. *B* is not represented.

The wider Altered Watercourse Assessment Team (AWAT) was consulted and they decided that the **Should Be** method was preferable because it would result in less underestimation of the extent of Altered type events. That is, although both methods may produce errors in the length estimations of Altered Watercourses, the **Should Be** method would produce significantly less.

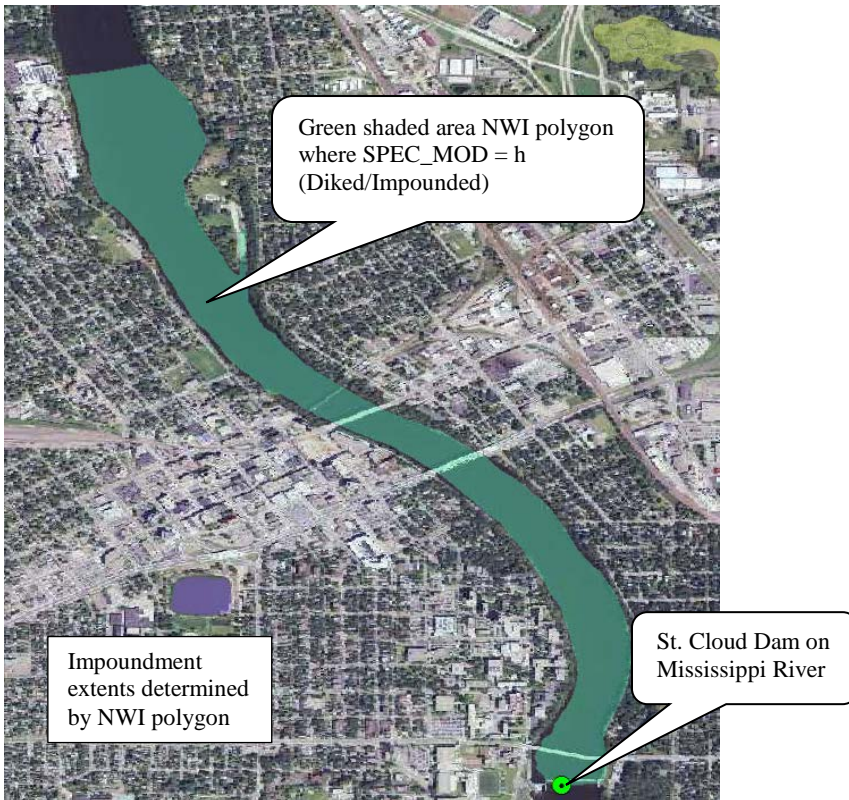
AWAT also decided to reserve the “No definable channel” designation for when no indication of a channel is present at all (e.g. lakes, wetlands, extreme headwaters).

Determining Impoundment Extents

For the purposes of this project an Impoundment was defined as a waterbody created by or whose level was controlled by a man-made dam. This included traditional impoundments created by the water behind a dam as well as water-filled gravel and mine pits and even natural lakes which have a dam at their outlet. It did not include beaver ponds which, although they are created by dams, tend to be ephemeral in nature and, of course, are not man-made.

The difficulty in some cases came about not so much in designating a waterbody as impounded or not but rather how far upstream the impoundment extended. On some rivers a clearly visible impounded waterbody does not exist. The Mississippi River is a good example. For much of its length the Mississippi is controlled by a series of dams that control the river’s flow yet in most places no clear impoundment is visible in the aerial imagery or LiDAR hillshade.

This is where some of the other reference data layers came in. It was decided that the NWI polygons where SPEC_MOD (Special Modifier field) = h (Diked/Impounded) or the DNR lakes polygons (e.g. PWI (Public Waters Inventory) or 24k lakes) would define the impoundment extents (see below). If neither of these existed behind a visible dam then it was presumed “offline” and the water behind it not impounded.



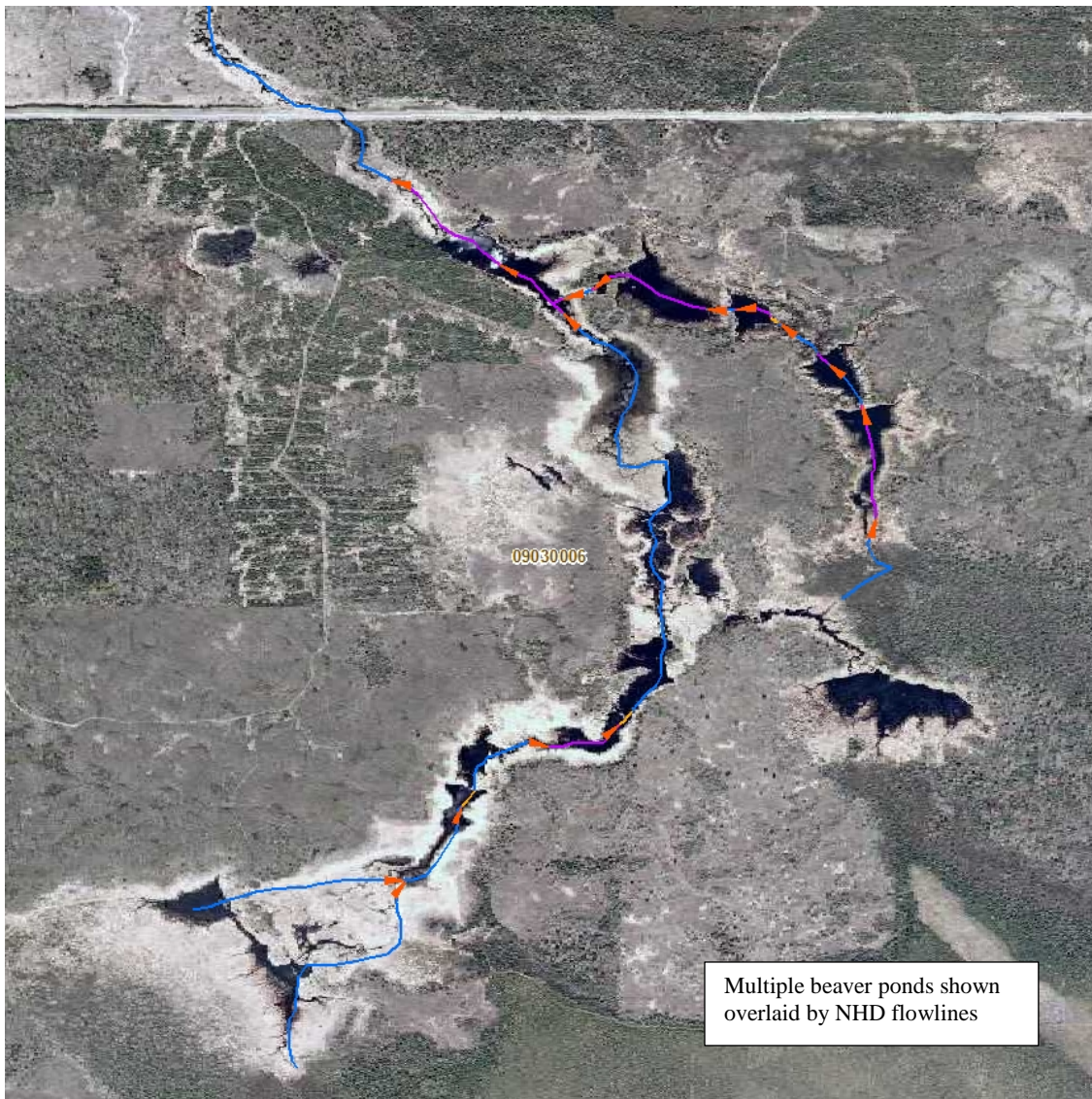
Beaver Dams & Ponds

Although MPCA was definitely not interested in designating beaver ponds as Impounded for the purposes of this project there was some question as to what they should be designated. Most beaver ponds were found to change from year to year on the aerial imagery but some persisted for 20 years or more. The question became: if these latter ponds are large enough (> 150 m in length) should the AW events within them be designated as No definable channel (criteria I), as though they are permanent waterbodies?

In addition, due to changes in yearly rainfall and the fact that some of the aerial photos were taken in the spring following snowmelt while others were taken during the drier summer months the beaver ponds could be seen to vary in size from year to year. A second question was: how should these size-changing ponds be handled?

At first it was decided that if a given beaver pond was visible in the 1991 USGS DOQs (Digital Ortho Quads) and still visible – at the same location – in the most current aerial photos then AW events traveling through it would be designated No definable channel (criteria I). The MPCA stipulated that although the pond may change size from year to year it may not otherwise change location. In these latter cases the events would be designated as Natural or Altered as appropriate.

This method clarification seemed sufficient until some of the HUC-8s of the Arrowhead were encountered (e.g. Little Fork – 09030005). Many of the streams in these watersheds were so “beaver-infested” that it was difficult to tell whether individual beaver ponds persisted or not for the stipulated time period (see below). To prevent potentially unending designation times on these stream reaches (mostly headwaters) the current method was abandoned. In its place all such events were designated as either Natural or Altered as appropriate with the statement “Area dominated by beaver activity” entered into their Notes field.



Appendix E: Working and Reference Layers

Layer Name	Layer Type(s)	Description	Use	Path
Altered Watercourse	Line	Event layer of concern	The layer to which Altered/Unaltered/Impounded/Unknown event features will be added	Personal Geodatabase on local drive
NHDFlowline	Line	Base stream network with uniquely identified reaches	The layer Altered Watercourse event features will be referenced to	Personal Geodatabase on local drive; Statewide copy on \\aquarius.lmic.state.mn.us.sde\NHDDist.Hydrography\NHDDIST.NHDFlowline_High
NHDArea	Polygon	Composed of 2-D stream data (i.e. wide rivers)	Helpful to delineate watercourse features (esp. Ftype = Stream/River)	Personal Geodatabase on local drive; Statewide copy on aquarius.lmic.state.mn.us.sde\NHDDist.Hydrography\NHDDIST.NHDArea_High
NHDWaterbody	Polygon	Composed of Lake/Pond, Reservoir and Swamp/Marsh polygons	Helpful to delineate waterbody features	Personal Geodatabase on local drive; Statewide copy on aquarius.lmic.state.mn.us.sde\NHDDist.Hydrography\NHDDIST.NHDWaterbody_High
WBD_HU12	Polygon	HUC-12 level of watersheds	HUC-12s useful to identify watershed boundaries internal to HUC-8s	Personal Geodatabase on local drive; Statewide copy on \\aquarius.lmic.state.mn.us.sde\NHDDist.WBD_Catchments\NHDDIST.WBD_hu12_a_mn
WBD_HU8	Polygon	HUC-8 level of watersheds	HUC-8s used to define work areas	Personal Geodatabase on local drive; Statewide copy on \\aquarius.lmic.state.mn.us.sde\NHDDist.WBD_Catchments\NHDDIST.WBD_hu8_a_mn
Historical Air Photos	Point, Raster	Points with links to aerial photography from the 1930's - 1980's from the Mn DNR	Helpful for determining hydrographic changes to landscape over time	Points: \\aquarius.lmic.state.mn.us.sde\GISDATA.DNR_HISTORIC_PHOTO_INDEX Photos: http://maps.dnr.state.mn.us/landview/historical_airphotos/...

MPCA Bio Sites	Point, Raster	Points with links to photos of stream biological sites monitored by MPCA	May help determine if given stream reach is altered, natural or impounded	Points: \\aquarius.lmic.state.mn.us.sde\GISDATA.MPCA_BIO_SITES_INDEX Photos: \\geoserver.state.mn.us\images
DNR Dams	Point	Latest MN dam data from the DNR Dam Safety Project	All but Status_of_ = Exempt - failed, Exempt - breached, Exempt - removed, Not built - withdrawn and Not built yet useful for locating 'impounded' watercourses	\\aquarius.lmic.state.mn.us.sde\GISDATA.Inland Waters\GISDATA.MN_NID_DAMS
GNIS Water Points	Point, Line	Official Geographic Names Information System proper names and IDs for hydrographic features	FEATURE_CL = canal, channel, dam, lake, reservoir, stream and swamp	\\aquarius.lmic.state.mn.us.sde\GISDATA.Inland Waters\GISDATA.GNIS_WATER_POINTS
DNR 24k Streams	Line	Watercourses captured from 1:24k USGS topo maps	STRM_TYPE = 40s, 70s, 80s, 90s are generally artificial	\\aquarius.lmic.state.mn.us.sde\GISDATA.Inland Waters\GISDATA.DNR_24K_Streams
DNR 24k Lakes	Polygon	Lakes derived from NWI polygons	May help define impoundment limits	\\aquarius.lmic.state.mn.us.sde\GISDATA.Inland Waters\GISDATA.DNR_24K_Lakes
PWI Basins (New)	Polygon	Public Waters Inventory Basins (lakes and wetlands) data as determined and regulated by the MN DNR - newest edited version - selected counties - not available on Deli	PWI_CLASS = P may help define impoundment limits; PWI_CLASS = W defines wetland limits (Note: The New PWI Basins supersede any old PWI basins which they overlap)	\\aquarius.lmic.state.mn.us.sde\GISDATA.Inland Waters\GISDATA.PW_Basins_New
PWI Basins (Old)	Polygon	Public Waters Inventory Basins (lakes and wetlands) data as determined and regulated by the MN DNR	PWI_CLASS = P may help define impoundment limits; PWI_CLASS = W defines wetland limits	\\aquarius.lmic.state.mn.us.sde\GISDATA.Inland Waters\GISDATA.PWI_BSNDPY3_OLD
PWI Streams (New)	Line	Public Waters Inventory watercourse data as determined and regulated by the MN DNR - newest edited version - selected counties - not available on Deli	PWI_Flag = 2 – Public Ditch/Altered Natural WC likely Altered WC. (Note: The New PWI Streams supersede any old PWI streams which they overlap)	\\aquarius.lmic.state.mn.us.sde\GISDATA.Inland Waters\GISDATA.PW_WATERCOURSES_NEW

PWI Streams (Old)	Line	Public Waters Inventory watercourse data as determined and regulated by the MN DNR	PWI_Flag = 2 – <i>Public Ditch/Altered Natural WC</i> likely Altered WC	\\aquarius.lmic.state.mn.us.sde\GISDATA.InlandWaters\GISDATA.PWI_WCDLN3_OLD
NWI	Polygon	National Wetland Inventory developed by USFWS through aerial photo interpretation and limited field verification studies	Special modifier fields (SPEC_MOD1 and 2) with the following values may indicate altered or impounded watercourses: <i>d=Partly Drained/Ditched, f=Farmed, h=Diked/Impounded, r=Artificial, s=Spoil, x=Excavated</i>	\\aquarius.lmic.state.mn.us.sde\GISDATA.nwi_c39py
Counties	Polygon	County Polygons	Helps show extent of project (Minnesota borders) as well as provide general geographic context	\\aquarius.lmic.state.mn.us.sde\GISDATA.CTY2000_WO
State_Boundary_Hybrid	Polygon	Minnesota boundary polygon created from combination of <i>Counties</i> layer and NHDFlowlines on/near the state border	Use to eliminate AW events outside Minnesota in HUC-8s that cross the state boundary	\\aquarius.lmic.state.mn.us.sde\NHDDIST.AWAT\NHDDIST.State_Boundary
DRG	Raster	Scanned USGS 1:24k, 1:100k and 1:250k scale topographic maps (Digital Raster Graphic)	Contours useful for determining elevation and relief; also shows hydrographic features	WMS: http://geoint.lmic.state.mn.us/cgi-bin/wmsz?
LiDAR	Raster	Light Detection And Ranging imagery from DNR ArcGIS Map Service and MnGeo WMS	Hillshade data is most useful for distinguishing stream channels, especially drainage ditches, but 2 foot contour data may also help. 3 m hillshade resolution is best but is not statewide.	DNR LiDAR: http://arcgis.dnr.state.mn.us/ArcGIS/services (ArcGIS Map Service) WMSs: \\Aquarius.gisdata.mngeo.sde\RASTER.MN_PINE_COUNTY, RASTER.REDRIVER_LIDAR, RASTER.SE_MN_LIDAR
Aerial Photography	Raster	Set of aerial photography layers that was produced from 1991 to present to include various areas of the state and consists of B/W, natural color and CIR imagery with resolutions ranging from 0.15 to 2 m.	Provides most direct evidence of altered, natural or impounded streams by showing recent hydrographic history of landscape through both wet and dry years and in various seasons. The highest resolution B/W and CIR imagery is usually best for distinguishing watercourse features while the natural color imagery has the latest and widest coverage.	WMS: http://geoint.lmic.state.mn.us/cgi-bin/wms?

Appendix F: Generating AW Events Only in Minnesota

The following procedures assume the analyst has already loaded the working and reference layers for a given HUC-8 into ArcMap.

1. If not done already, select all NHDFlowlines of the given HUC-8.
2. Start editing on Altered Watercourse layer.
3. On the HEM toolbar, select **Task: Create Line Event** and **Target: Altered_Watercourse**. This sets the AW layer as the output for the next operation.
4. Create Altered_Watercourse events from the selected flowlines by using the **HEM > Edit Tools > Import Selected Flowlines** tool. Click **OK** button on dialog that appears saying: "Could not find table NHDReachCode_ComID in the database. No date will be set for this row."
5. Click the **Save to Report** button on the Import Flowlines Report dialog and save the text file report as *Import.txt* to the local directory that contains your HUC-8. Also click **Close** button. Note: If "Failed to Import Flowlines" > 0 in report, quit edit session without saving and rerun steps 1-4. Report any persistent errors to Jim & Susanne.
6. **Save** edits and **stop** editing.
7. **Save** mapfile locally to same local directory that contains your HUC-8 and **close** ArcMap.
8. In ArcCatalog, right-click on your HUC-8 geodatabase and select **Import > Feature Class (single)**
 - a. Input Features: ...\\State_Boundary_Hybrid.shp
 - b. Output Location: <local HUC-8 geodatabase> (default)
 - c. Output Feature Class: State_Boundary_Hybrid
9. In ArcToolbox, run **Analysis Tools > Extract > Clip**
 - a. Input Features: Altered_Watercourse
 - b. Clip Features: State_Boundary_Hybrid (feature class created in step 7)
 - c. Output Feature Class: Altered_Watercourse_Clip (default)
10. In ArcCatalog, **delete** original Altered_Watercourse layer.
11. **Rename** Altered_Watercourse_Clip to Altered_Watercourse.
12. **Reopen** the saved mapfile in ArcMap.
13. The new version of the Altered_Watercourse layer should be visible (i.e. events only within the state boundary).
14. Continue with step 13 on page 9.

Appendix G: Attribute QA/QC Script Integrity Errors

Attribute QA/QC (by AW_attribute_checker.py python script)

Error Description

Errors that stop the script

- AW feature class does not exist
- No records in AW feature class table

Errors that do not stop the script

Test #	<u>NULLs or Bad Values</u>
1	NULL or Bad values in ComID, AWEvtType, Confidence, NHDUpdate and CritLetter
2	NULL CritNum1 values if CritLetter = D, E, F, G, L, M, N
3	NULL CritNum2 values if CritLetter = E, F, M, N
4	NULL CritNum2 values if CritLetter = G and Confidence = Medium or High
5	NULL CritNum3 values if CritLetter = F, N
6	NULL CritNum3 values if CritLetter = G and Confidence = High
7	CritNum1, CritNum2, CritNum3 not NULL when CritLetter = A, B, C, H, I, J, K
8	CritNum2, CritNum3 not NULL when CritLetter = D, L
9	CritNum2, CritNum3 not NULL when CritLetter = G and Confidence = Low
10	CritNum3 not NULL when CritLetter = E, M
11	CritNum3 not NULL when CritLetter = G and Confidence = Medium or Low
	<u>Invalid CritLetter values given AWEvtType and Confidence values</u>
12	Invalid CritLetter when Event Type = Altered and Confidence = High
13	Invalid CritLetter when Event Type = Altered and Confidence = Medium
14	Invalid CritLetter when Event Type = Altered and Confidence = Low
15	Invalid CritLetter when Event Type = Natural and Confidence = High
16	Invalid CritLetter when Event Type = Natural and Confidence = Medium
17	Invalid CritLetter when Event Type = Natural and Confidence = Low
18	Invalid CritLetter when Event Type = Impounded and Confidence = High
19	Invalid CritLetter when Event Type = Impounded and Confidence = Medium
20	Invalid CritLetter when Event Type = Impounded and Confidence = Low
21	Invalid CritLetter when Event Type = No definable channel and Confidence = High
22	Invalid CritLetter when Event Type = No definable channel and Confidence = Medium
23	Invalid CritLetter when Event Type = No definable channel and Confidence = Low
	<u>Out-of-range values (not 1-9 or 11-18) for CritNum1, CritNum2, CritNum3 if CritLetter = D, E, F</u>
24	CritNum1 out-of-range (not 1-9 or 11-18) when CritLetter = D
25	CritNum1 or CritNum2 out-of-range (not 1-9 or 11-18) when CritLetter = E
26	CritNum1 or CritNum2 or CritNum3 out-of-range (not 1-9 or 11-18) when CritLetter = F

Out-of-range values (not 21-27) for CritNum1, CritNum2, CritNum3 if CritLetter = G

- 27 CritNum1 out-of-range (not 21-27) when CritLetter = G and Confidence = Low
- 28 CritNum1 or CritNum2 out-of-range (not 21-27) when CritLetter = G and Confidence = Medium
- 29 CritNum1, CritNum2 or CritNum3 out-of-range (not 21-27) when CritLetter = G and Confidence = High

Out-of-range values (not 31-39) for CritNum1, CritNum2, CritNum3 if CritLetter = L, M, N

- 30 CritNum1 out-of-range (not 31-39) when CritLetter = L
- 31 CritNum1 or CritNum2 out-of-range (not 31-39) when CritLetter = M
- 32 CritNum1 or CritNum2 or CritNum3 out-of-range (not 31-39) when CritLetter = N

Duplicate values

- 33 Duplicate value between CritNum1, CritNum2, CritNum3

Appendix H: Continuity Errors for HUC-8s That Cross the State Boundary

The following steps allow the analyst to determine if the **no event** errors generated by the Check Continuous Events tool pertain to flowline reachcodes either inside or outside the state boundary. Only those errors within Minnesota need to be fixed. The other types of continuity errors (**gaps** and **overlaps**) need to be checked one-by-one if they are within Minnesota using the Geographic QA/QC procedure found on pp. 17 -19. Note: *NHDFlowline* below refers to the local, not the statewide SDE version of the layer.

1. Load the mapfile of your HUC-8 into ArcMap.
2. Load the **Altered_Watercourse_err** table from the latest version of the HEMContEvtQC_<YYMMDDHHNNSS> geodatabase. (Second half of filename is timestamp where: YY = 2-digit year, MM = 2-digit month, DD = 2-digit day, HH = 2-digit hour, NN = 2-digit minute and SS = 2-digit second (e.g. HEMContEvtQC_120214043104))
3. **Relate** Altered_Watercourse_err.ReachCode to NHDFlowline.ReachCode
4. **Select By Attributes:**
 - a. Layer: Altered_Watercourse_err
 - b. Method: Create a new selection
 - c. WHERE: [ERROR_TYPE] = 'NO EVENTS'
5. **Initialize** relate to NHDFlowline table
6. **Select By Location:**
 - a. Selection method: remove from currently selected features
 - b. Target layer: NHDFlowline
 - c. Source layer: State_Boundary_Hybrid
 - d. Spatial selection method: Target features are within Source layer

The selected flowlines have *no event* errors outside of Minnesota and so do not need to be fixed. They do need to be noted, however, in the Altered_Watercourse_err table.

7. **Initialize** relate from NHDFlowline table back to Altered_Watercourse_err table
8. **Calculate** Altered_Watercourse_err.Repaired field = 1 for selected records to indicate that these have been verified.
9. **Switch Selection** of Altered_Watercourse_err table.
10. If **any** records are selected, go to step 2 of the Geographic QA/QC procedure (p. 17). These are the reachcodes that have flowlines within Minnesota that need to be fixed.
11. If **no** records are selected, go to step 1 of the Attribute QA/QC procedure (p. 19).

Appendix I: Question and Answer Table

Some of the questions and answers encountered during the project.

Number	Question or Comment	Staff	Date Entered	Answer (or additional comment)	Answerer	Date Answered
1	Should AW events be single or multi-route in HEM?	JK	11/16/2011	Single to make it compatible with NHD.	Susanne	11/17/2011
2	What parts of watercourses that go out of state and come back should be assessed?	JK	11/16/2011	Designate only those watercourses within Minnesota.	AWAT	11/16/2011
3	Should flowlines in oxbow lakes be defined as "No definable channel" (waterbody) or "Natural" (2D Area)?	JK	11/16/2011	"No definable channel" (waterbody) if cut off from main channel.	AWAT	11/16/2011
4	Should dredged watercourses be automatically defined as "Altered"?	JK		Not unless the horizontal extent (i.e. sides) of the channel are changed.	AWAT	
5	Should restored streams be designated as altered or natural?	JK		Altered but enter "recovering" or "restored" in Notes field.	AWAT	
6	Should WC depth be considered a factor in determining "WC" versus "swale"?	AB	12/6/2011			
7	Should we include people from USDA, Minn Dept of Ag or U of MN Extension Office in AWAT for their farm area and ditching expertise?	JK	12/8/2011			
8	How should we define valid waterbodies for this project? (Suggestion: The waterbody meets NHD capture standards (≥ 100 foot (~30m) width) on more than half of the available years of modern aerial photography - from 1991 to current.)	JK/MW	1/6/2012			
9	How should we define valid impoundments for this project? How far upstream of a dam should an AW event be designated as impounded? (Some impounded waterbodies are obvious but others are not.) What about dried-up impoundments? How trustworthy is the NWI SPEC_MOD field?	JK/AB	1/20/2012			
10	Are NHEdit QA/QC severity = 3 errors a problem for HEM, especially the Continuity Checker?	JK	9/25/2012	Microgaps are, circular reaches (e.g. islands) could be if reaches are split, isolated networks are not	Ariel D. (USGS)	9/25/2012
11	How should we handle watercourses with dams that do not have impoundments visible in aerial photos? If we require WBs (impoundments) to be visible then except for cases like Spring Lake (in the south metro) the dams on the Mississippi (and other large rivers) will consequently not have impoundments. Is this what we want?	JK	10/25/2012	If a dam is visible but an impoundment is not on most years of aerial imagery then use NWI or DNR lakes layers (24k and PWI) to define impoundment extent. If neither NWI nor DNR lakes data shows an impoundment then consider event(s) upstream of dam NOT impounded.	Ben & Scott	
12	We currently keep the entire tributary flowline to a 2-D stream (large river) with the same AW atts (i.e. altered stays altered even within the 2-D area) but have all tributary flowlines within a lake/pond as Impounded or Not defined channels. However, how should we handle waterbodies like Lake Pepin on large rivers?	JK	11/1/2012	With situations like Lake Pepin designate the interior events as No definable.	Ben	2/1/2013
13	Do latter-day aerial imagery (e.g. 2010 and later) take precedence over earlier imagery in making AW determinations or should a majority of aerial imagery years be used instead?	JK	2/8/2013	In general, put more weight on 1991 b/w imagery, historical air photos and lidar hillshade than latter years of aerial imagery (e.g. 2003-current) to determine if an event is definable or not.	Ben	2/12/2013
14	How should we handle water-filled gravel and mine pits with NHDFlowlines running through them? They may already fulfill criteria (e.g. 31, 37) as impoundments even without a dam. Should they be essentially equivalent to impoundments?	JK	3/6/2013	The associated events in such a situation should be considered no definable unless there is conclusive evidence that a dam exists in which case they would be considered impounded.	Ben & Scott	3/6/2013
15	Stream channels flowing through wetlands are sometimes indistinct. When are they 'No definable channel'?	SRM	4/26/2013	If you can see water in the channel in a couple years of photos and the surrounding land has not been developed or modified since then it is definable.	Ben & Scott	4/26/2013
16	When to split events for distances less than 150 meters?	SRM	4/26/2013	Only when the too-short event is adjacent to another event of the same type and together they are greater than 150 m.	Ben & Scott	4/26/2013