Ioway Creek

Brookside Park, Ames, IA

Existing Conditions Assessment & Restoration Concept

NREM 455L/555L, fall 2021
Iowa State University

Disclaimer

This document presents a summary of a semester project completed by the students of NREM 455L and 555L: Stream Restoration, at Iowa State University, fall semester 2021. The instructor and students are not licensed engineers and cannot formally certify the accuracy of findings or the appropriateness of recommendations. Even so, we hope that this document can provide ideas and catalyze discussion about possible approaches to restoring Ioway Creek. Questions or comments can be addressed to Dr. Pete Moore, pmoore@iastate.edu, 339 Science II, Iowa State University, Ames, IA 50011.

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EXECUTIVE SUMMARY

Brookside Park is a popular city park near the center of Ames, IA, and represents the hub of a public greenbelt and nature corridor along Ioway Creek (formerly Squaw Creek). Unfortunately, the creek presents some challenges for park and stormwater managers as well as neighboring landowners. Streambank erosion threatens park and city infrastructure in several places, including the multi-use trail that connects 6th Street and 13th Street through Brookside, two footbridges, and four stormwater outfalls. Erosion and instability of a tall bluff on the east bank threatens the property and structures of at least two homeowners in the adjacent neighborhood. Despite being the focal point of the park, public access to Ioway Creek within the park is limited and relatively unsafe.

Herein, we present the results of five weeks (approximately 12 hours) of field assessments, desk analysis including assessment with the Iowa River Restoration Toolbox (IRRT), and several stakeholder discussions.
Initial field assessments and stakeholder discussions led to development of a series of proposed project goals. Priority goals include:

- Protecting city and landowner property from erosion and land loss
- Maintain or improve lateral and vertical channel stability
- Reduce or avoid heightening flood hazard through the Ioway creek corridor

In addition to these priority goals, we identified the following additional goals:

- Improve safe public access to the creek
- Maintain or improve aesthetic/natural character of the park
- Maintain or improve habitat for fish and wildlife that use the park and/or creek
- Maintain or improve water quality

Field study of the creek in Brookside Park focused on the reach between footbridges within the park, where most of the threats are present. Here, we found the channel to be a low-sinuosity and low-gradient, incised, mostly sand-bedded stream with a poorly-defined pool and riffle channel pattern. Banks are tall and steep, showing evidence of active bank erosion and past incision, but little evidence of ongoing incision. The creek is best characterized as a C4c- stream type in the Rosgen classification system, but due to past incision and mostly-sandy bedload, it lies near the boundary between C and F stream types and 4 and 5 bed material types.

While the Ioway Creek channel upstream of the northern footbridge in Brookside has complex geometry and diverse habitats for both aquatic and terrestrial fauna, the reach between footbridges is less diverse. Pools and glides dominate habitat types, and no well-developed riffles are present. Our survey identified two riffle units, but both were short, poorly-defined, and composed in part of anthropogenic materials. Large wood volumes were below those expected of forested stream corridors of similar size in the region. Low water conditions prevented us from completing a formal benthic macroinvertebrate survey of the reach, but some pollution-sensitive families were noted informally, despite the creek's past record of poor water quality. No formal mussel or fish surveys were completed either, but we observed a few mussels as well as individuals of several fish species during our physical habitat survey, including smallmouth bass, northern hogsucker, and various minnows.

The channel appears to be in late stage 4 or early stage 5 of channel evolution, showing clear indications of widening and some signs of aggradation. Channel stability is rated as fair, but a bank erosion assessment indicates that more than two thirds of the channel banks are severely- or very-severely eroding according to an NRCS qualitative assessment scheme. The resulting within-reach sediment supply, which we estimate to be approximately 280 tons annually (384 pounds per foot of channel length), may alone be sufficient to exceed sediment transport capacity and lead to aggradation. Excess supply from banks, as well as additional supply from upstream must be stored within the reach by channel-bottom aggradation and bar formation, both of which appear to be occurring.

A decision matrix included with the IRRT identified five attributes of our reach that were problematic (functional-at risk or non-functional): bank-height ratio, bankfull cross-sectional area and bankfull discharge, channel evolution stage, and bank erosion hazard. The large bank-height ratio is indicative of past or ongoing incision, such that the stream accesses the floodplain less frequently than would be expected of a stable channel. Stage 4-5 channel evolution points to lateral instability in the form of channel widening, consistent with the elevated bank erosion hazard. These are also consistent with the finding that bankfull cross-sectional area is elevated compared with the provisional Iowa regional curve.

Considering these findings, we identify several related problems that could be addressed in a rehabilitation project, and a collection of modular elements that could contribute to the rehabilitation effort. In general, widespread bank erosion and corresponding channel widening is undesirable in this setting, and a design that mitigates these problems could address all three of our priority goals. Because of the in-reach sediment supply and what appears to be an ample supply from upstream, we don’t believe that incision is currently a problem, and indeed are concerned that any grade control structures used within this reach could become buried and ineffective if placed in over-widened sections. However, actions that reduce within-reach and upstream sediment supply such as bank stabilization and channel definition could contribute to a reduction in the aggradation tendency.
A critical problem area is approximately midway between footbridges (starting near station 6+00), where an eastward jog in the creek causes the channel to scour the toe of the till bluff on the eastern edge of the park (stations 7+00 to 10+00). This bend appears to be forced by a convex section of the right (west) bank that is heavily armored with slabs of broken concrete, which directs flow downstream toward the left (east) bank where the most severe bluff-toe erosion begins. We have found no indication that this armored bank protects existing infrastructure or high-value park amenities. Thus, barring any new information about the purpose of that bank-armor structure, our highest-priority rehabilitation element includes the removal of the concrete armor there and flattening of that bend. Additional elements or modifications could include:

- Bank re-shaping and re-vegetation
- Stone or wood toe protection on critical banks
- Bankfull bench establishment accompanying any channel re-alignment

In one alternative, realignment of up to 800 feet of channel could be accompanied by the creation of a broad bankfull bench and storm-water-treatment oxbow wetland near the base of the till bluff.

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1. FIELD ASSESSMENT: EXISTING CONDITIONS

1.1. Geographic scope and context

Brookside Park is located within walking distance of Iowa State and Downtown Ames. It provides pubic space for sports, gatherings, and all-season recreation. Ioway Creek runs along the eastern and northern edges of the park. The creek drains a watershed of just over 200 square miles upstream of Brookside. There are two pedestrian foot bridges in the park that crossover Ioway Creek. Between these footbridges exists several degraded stormwater outfalls, old riprap, and a highly degraded bluff that makes up the east boundary of the park. The stream is also very straight through this section. Ioway Creek, like any alluvial system, exists as a meandering stream within a river valley. The degraded bluff in question is part of the valley wall.

Figure 1: View of the till bluff east bank of Ioway Creek in Brookside Park from approximately station 11+00 (see Figure 2). Flow is from left to right.

This degrading bluff is the driver behind the need to restore the stream. Inaction here threatens private property, the utility of the stream as a stormwater conveyance system, biotic integrity, and the recreation potential of Ioway Creek. Nearby infrastructure constraints mean that the restoration of the channel should insist upon creating a stabilized channel that does not migrate. The nature of a stabilized channel compromises stream functions that can sustain healthy environments. Functioning, dynamic aquatic and riparian ecosystems are difficult to maintain when dynamic channel processes are stabilized.

1.2. Key features

Starting 900 feet downstream from where Ioway Creek flows under the 13th Street bridge, the paved multi-use trail approaches and traverses along the left bank. This bank is currently partly protected by broken sidewalk riprap. Though our assessment does not include this reach of the creek, we identify this as an area where bank stabilization may need to be updated. The assessment in this report begins at the northernmost footbridge and ends at the southernmost footbridge.

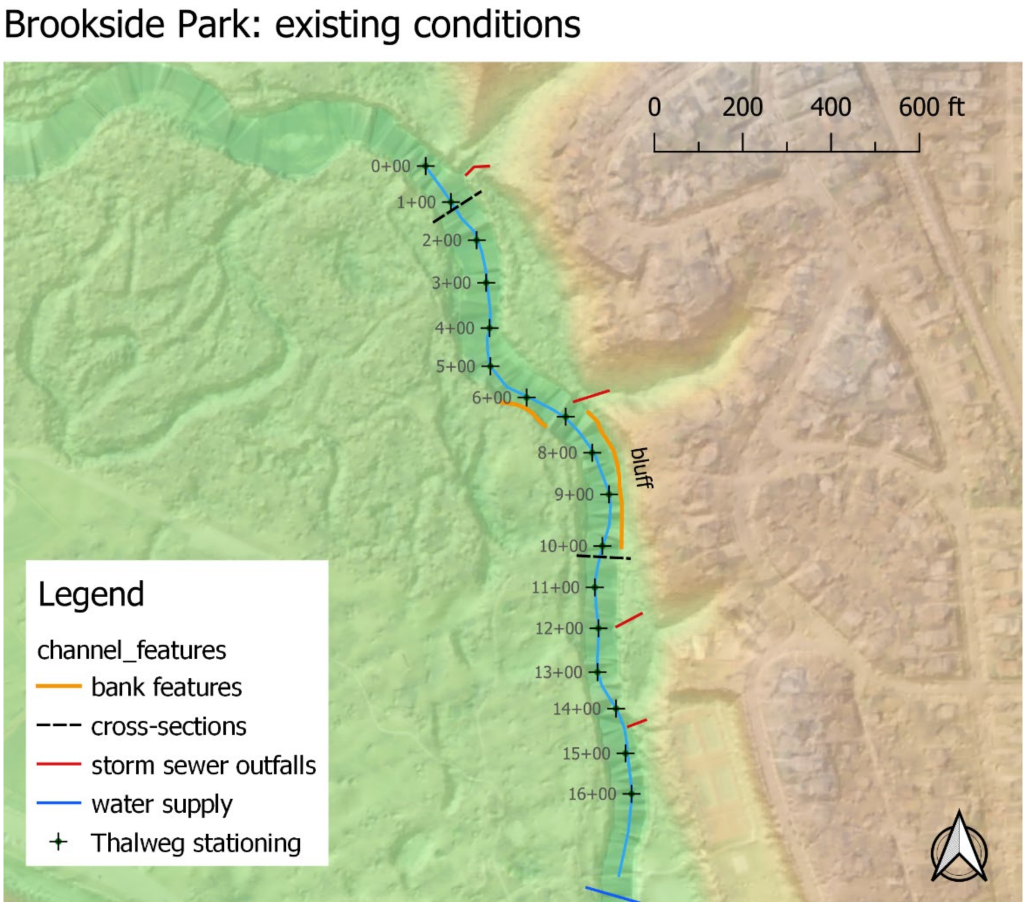


Figure 2. Survey station numbers (feet downstream from the northern footbridge in Brookside Park) and key features observed in the preliminary field survey.

Just downstream of the northern footbridge, a small storm sewer outfall on the east bank drains in to the creek. It has a damaged outlet apron and enters the creek through a short gully. The outfall and gully are poorly armored with broken chunks of old sidewalk. Downstream of that there is a section of undeveloped floodplain along both banks. About 500 feet downstream of the footbridge, there is large wood (also referred to as "large woody debris") in the creek that spans most of the width of the channel. This large wood creates a diversity of flow regimes and potential habitat for aquatic species. There is also a large scour pool immediately downstream of the large wood, providing refuge for aquatic life during dry conditions. After that, the creek turns east. In the section that bears east – or about 650 feet downstream of the north footbridge, the west bank features another section of broken sidewalk doubling as bank armor. The east bank features a culverted storm drain that enters the creek. After that, Ioway creek largely straightens out compared to upstream sections. As previously mentioned, this is due to the stream running up against its valley wall and being confined there. The

Figure 3. Photo of existing broken-concrete riprap along the right bank of Ioway Creek between stations 6+00 and 7+00.

severely eroded bank of concern starts here along the left (east) bank. This bank is riddled with slump scars and overhanging root wads where soil that the roots germinated into has eroded away. There is also evidence of previous attempts to armor the toe of this slope. Stone and concrete riprap appears in several sections along the bank here. The right (west) bank here is also in poor condition, though not showing recent signs of mass wasting. In the channel, there are mid-channel bars and signs of aggradation. Further downstream, there is a small section of floodplain along the left bank protecting the river bluff, but with severely eroded banks. Root wads are overhanging undercut sections of bank. Continuing downstream, there is another section of large wood creating hydraulic and environmental diversity. At the tennis courts – or about 1200 feet downstream of the north footbridge – there is another storm sewer outfall along the left bank that is in a state of disrepair. At the same location, the right bank is armored, although this is not a cutbank. After the armoring, there is a large fallen cottonwood tree spanning the creek that serves as a bridge for wildlife, judging from scat piles. Another 50 or so feet downstream is the southern footbridge. Just downstream of that, a grade control structure prevents incision from exposing the city water line serving the park. According to USGS stream stats, 94 percent of the soils in this watershed are type B, and 5 percent are type C soils.

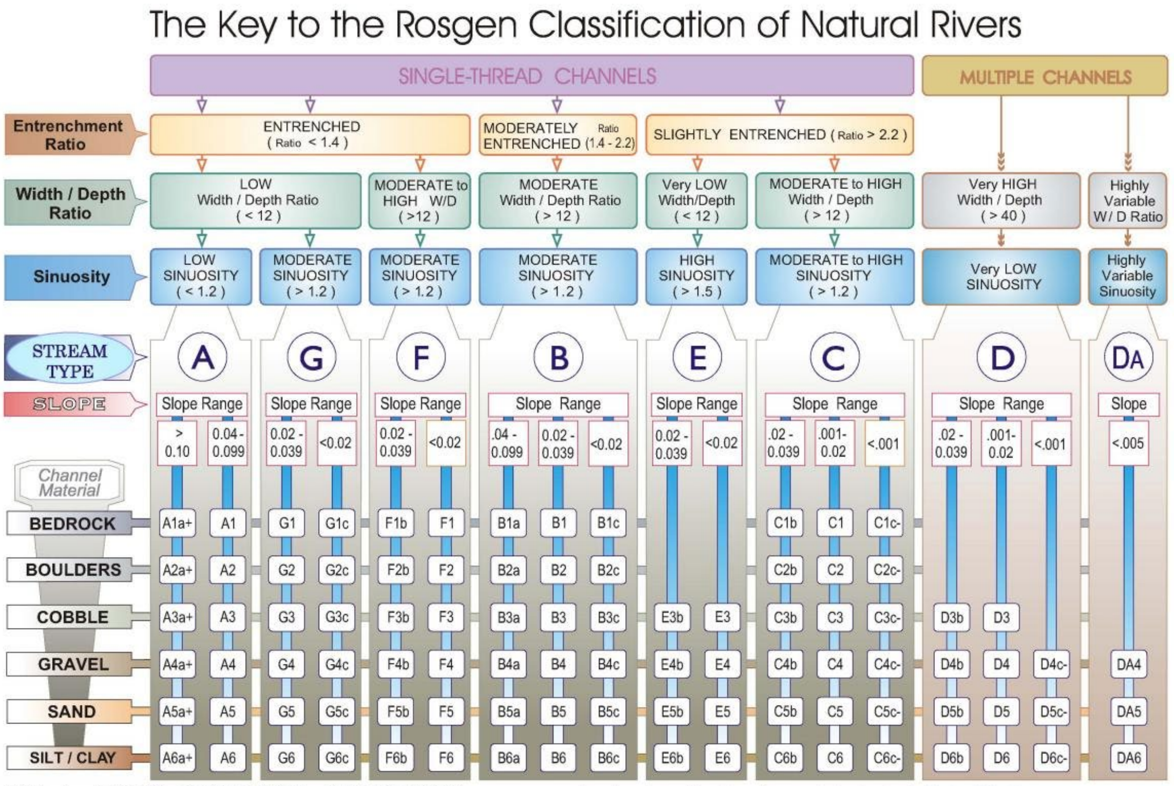
1.3. Channel Morphology

In order to begin assessing the condition of the stream in the context of the Iowa River Restoration Toolbox (IRRT), it is necessary to determine the morphological classification of the stream. IRRT uses the Rosgen Channel Classification System, which relies on making observations and measurements of channel geometries. The first observation and measurement to make is that of bankfull calls. In an equilibrium alluvial channel, bankfull height would be the exact elevation where water begins spilling into the floodplain. Typically, this has a recurrence interval between 1 and 2 years. In degraded systems, bankfull stage is often considerably lower than the floodplain, and produces “markers” that must be identified in the field. There is subjectivity to this, and therefore the reported Entrenchment Ratio may be an underestimate.

Following identification of bankfull stage, a long profile and several cross-sections were measured to determine bankfull geometry and planform parameters. Width to Depth ratio is calculated as the width of the channel at bankfull stage divided by the maximum bankfull depth. Ioway Creek was determined to have a Moderate to High Width to Depth ratio. Sinuosity is measured as the length of the thalweg of the channel in the reach divided by the length of the valley between the same two points (in this case, a straight line). Ioway Creek has low to moderate sinuosity.

The slope of the channel was simply measured by surveying the long profile of the channel and dividing the total bankfull elevation drop over the reach by the channel length. Slope is low, less than 0.001 (~0.0007 ft/ft).

There is also a reliance on average grain size of bed material. This is less subjective than the bankfull calls, but for Ioway Creek, stream bed sediment grain size is borderline between sand and gravel grain sizes. Below, Figure 4 shows the entire Rosgen Classification System.



KEY to the *ROSGEN* CLASSIFICATION of NATURAL RIVERS. As a function of the *"continuum of physical variables"* within stream reaches, values of ***Entrenchment*** and ***Sinuosity*** ratios can vary by +/- 0.2 units; while values for ***Width / Depth*** ratios can vary by +/- 2.0 units.

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Figure 4. Rosgen Classification System. Reproduced from Wildland Hydrology, Inc.

1.3.1. Channel Classification

Due to the potential variance in our measurements, Ioway Creek falls near four different classifications. The four possible classifications are C4c-, C5c-, F4, and F5. When using the IRRT, it determined that Ioway Creek in Brookside Park is a C4c- stream. However, that determination is made assuming no ambiguity in field measurements. Since C4c- is the best fit for the measurements and observations made, it was used for assessment and design decisions throughout this report.

1.4. Channel dynamic trajectory

Based upon field measurements and observations described in this report, Ioway Creek is most likely in Stage 4 or 5 of Channel Evolution. Though the tall, steep banks and evident disconnection from the floodplain suggest past incision, it is likely no longer incising judging by the presence of large accumulations of bed material (mid-channel bars). This may be due to a combination of high sediment supply and existing grade control structures downstream. There is evidence that it is widening due to the signs of erosion and mass wasting events seen along the over steepened banks throughout the entire reach. Figure 5 below is a simplified conceptual model for natural stream evolution. In addition to the mass wasting and widening, Stage 4 and 5 show the entrance of large woody debris into the channel. A stream that is actively incising (Stage 3) will not show extensive mass wasting that widens the channel, or growth of mid-channel bars that represent aggradation.

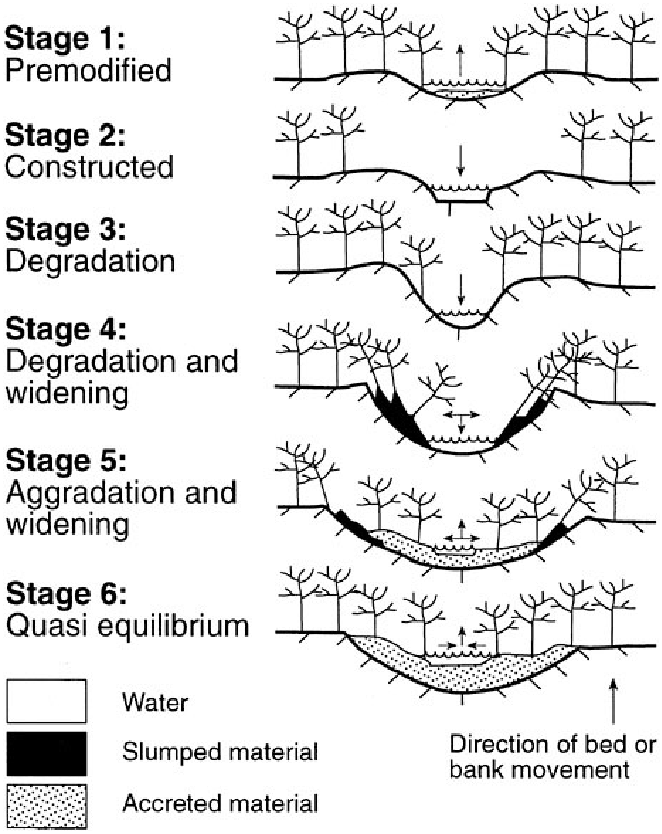


Figure 5. The 6-stage channel evolution model of Hupp and Simon. Ioway Creek shows indications of both Stages 4 and 5 within Brookside Park.

2. HYDROLOGIC AND HYDRAULIC CONTEXT

2.1. Hydrology at USGS gage 05470500

A USGS gage station (#05470500) exists downstream of Brookside Park near the Lincoln Way bridge over Ioway Creek. While this station was active as early as 1919, it was inactive from 1927-1964. Since 1965, however, there is a nearly-continuous record of flow. Though a few small tributaries (e.g., College Creek) enter the creek between Brookside Park and the gage, we consider the gage to be representative of the flow regime within Brookside.

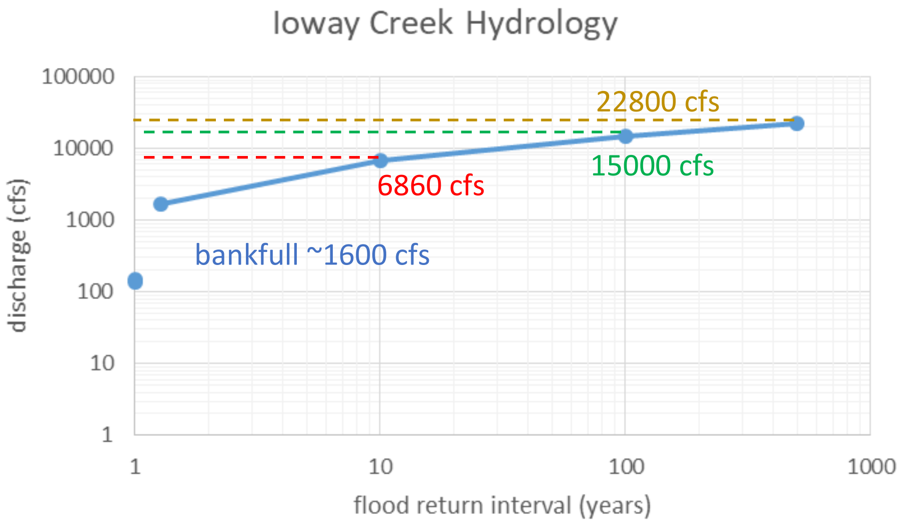
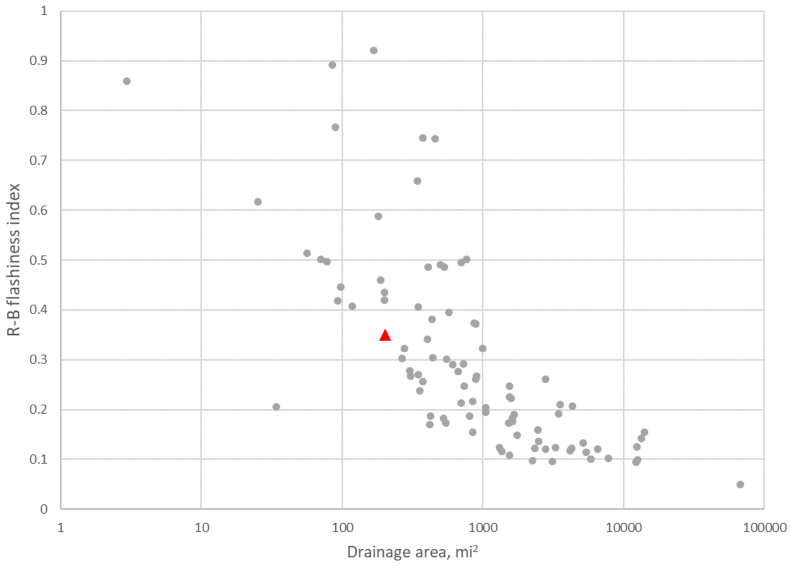


Figure 6. Peak flow data for design-relevant events at station 05470500, Ioway Creek at Lincoln Way.

The data used to make the graph above (Figure 6) is from the USGS Streamstats compilation of NWIS data. The points correspond to discharge at the annual mean, existing-conditions bankfull, 10-year, and extrapolated 100- and 500-year floods. Most of Brookside Park falls within the FEMA floodplain for the 100-year (1% AEP) flood event.

A few important questions about stream character arise when thinking about resilient design. Is the stream's flow regime unusual in any way? Does the gage record indicate that flow regime is changing over time, either due to extrinsic factors like climate or due to within-basin changes in land use or stormwater routing?

Figure 7. R-B flashiness index plotted as a function of drainage basin area (log-scale) for USGS gages in Iowa. Ioway Creek is shown as a red triangle.



To address these questions in the context of a partially-urbanized Ioway Creek catchment, we explored the possibility that Ioway Creek is unusually flashy. To evaluate this, we used the Richards-Baker (or R-B) flashiness index, computed for all gage stations in Iowa with at least 20 years of record (Figure 7). Ioway Creek (red triangle) appears to be no more flashy than other Iowa streams in its size range, and is perhaps less so. However, there does appear to be some non-stationarity to the discharge records. Figure 8 shows the median of each year's daily mean discharges from 1965 to 2018, along with a best-fit trendline. While we don't expect any strong correlations to be present in a time series like this, there is an indication at all quantiles of the discharge record of a positive trend. In other words, Figure 8 indicates that the median discharge is increasing by an average of more than 0.5 cfs per year, or nearly 1% per year. This suggests that a conservative and climate-adaptive design approach should incorporate some expectation of increased flows in the coming decades.

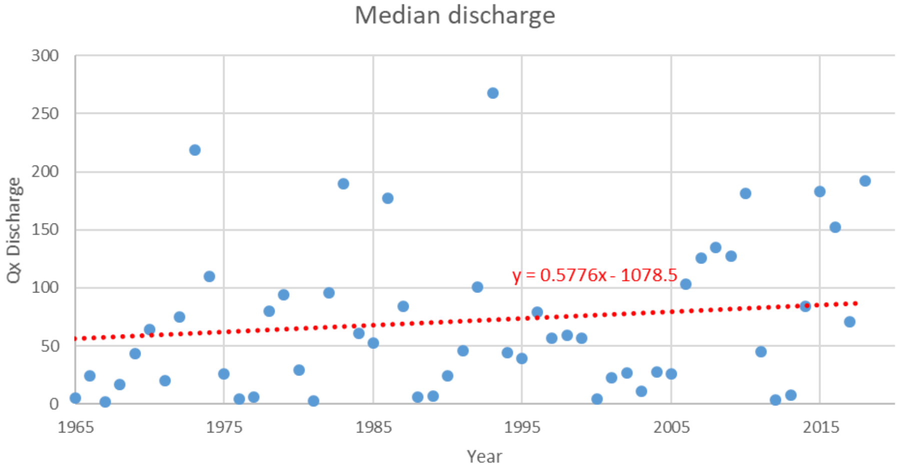


Figure 8. Median daily discharge for each year since 1965 at the USGS Ioway Creek gage.

2.2. Flow duration curve analysis

Using historical daily mean discharge data from the USGS gage station at Lincoln Way, Ames, flow duration curves for four equal time periods were constructed and compared. A flow duration curve uses daily mean discharge data from a time period to display how often discharges exceed a given value. Data used for the analysis spanned the years from 1919 to 2021, though some years were present where no data was collected. Figure 9 shows flow duration curves for four 8-year periods during which there was an unbroken record of data.

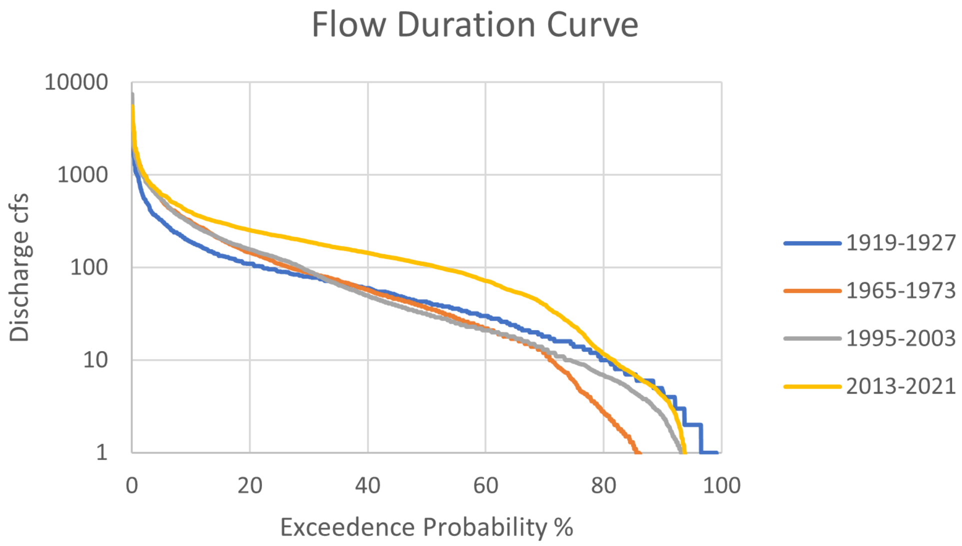


Figure 9. Flow duration curve for four 8-year intervals between 1919 and 2021. Plotted using daily mean discharge data from the USGS gage station 05470500 on Ioway Creek at Lincoln Way, Ames.

The flow duration curves show that there has been a shift in flow magnitude and frequency throughout the studied time periods, consistent with the analyses above. The 1919 -1927 interval shows that a flow of 100 cfs was exceeded only approximately 20% of the time during those eight years. Whereas the flow of 100 cfs during the 2013- 2021 interval was exceeded approximately 55% of the time. This means that Ioway Creek at Lincoln Way is transporting higher flows more frequently during the past 8 years than it did in any of the other intervals. This could be attributed to urbanization upstream and additional storm water outlets installed without retention basins, or could reflect an extrinsic change in streamflow that has been widely observed in the U.S. starting in the 1970s (McCabe and Wolock, 2002). This analysis is important because there may be design implications associated with the increased flows. This data suggests the channel of Ioway Creek at Brookside Park may need to accommodate larger flows than the drainage area might indicate.

2.3. Bankfull discharge estimate

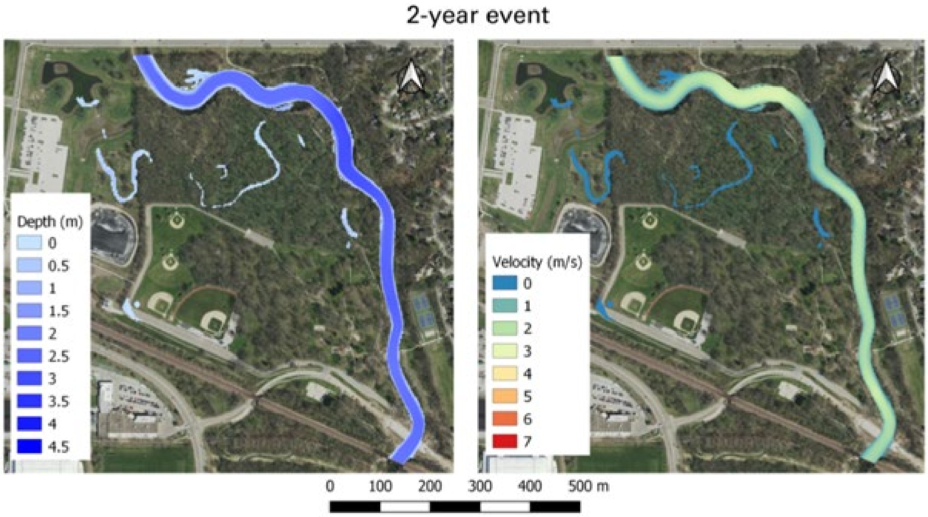
Using measurements collected in the field, riffle cross-section data, and Manning's equation written in terms of discharge, we were able to estimate bankfull discharge for the reach of Ioway Creek within Brookside Park. From field measurements at one stable cross-section, we estimate the bankfull stage to be about 4.8 feet above the mean channel bed elevation. Manning's equation in this form and U.S. customary units is:

$$Q = \frac{1.49}{n} A R^{2/3} S^{1/2}$$

where roughness n = 0.035, hydraulic radius R = 4.8 feet, cross-sectional area A = 484 ft^2, and water surface slope S = 0.0007. Using this method, bankfull discharge is approximately 1500 cfs, though incorporating uncertainty in parameter values, we identify the range 1300-1800 cfs for bankfull discharge. This estimated range compares well with the provisional Iowa regional curve for bankfull discharge, which indicates a bankfull discharge of 1492 cfs for a basin the size of Ioway's.

2.4. Hydraulic modeling of existing conditions

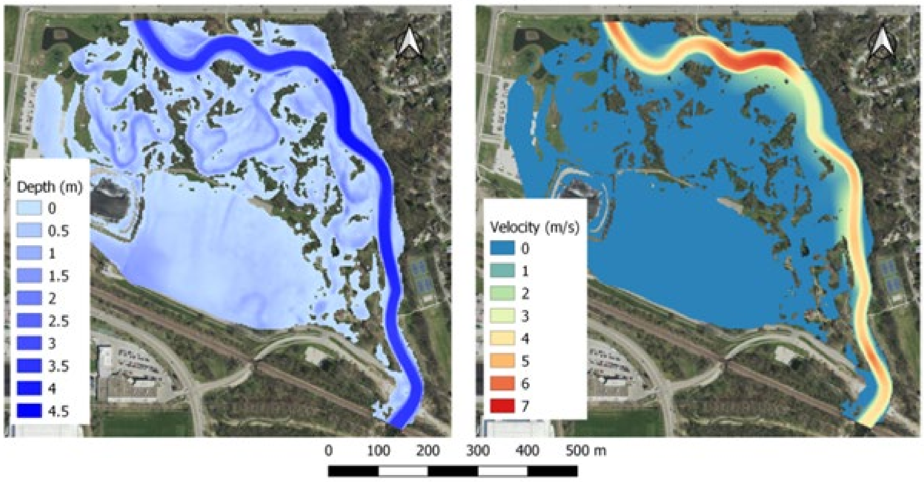
Hydraulic modeling is a useful and often necessary tool in stream restoration. The use of a hydraulic modeling program, in this case, 1D HEC-RAS, is needed to show depth and flow velocity of different magnitude discharges for existing conditions. The results of the simulation could highlight any problem areas within the reach, areas of high velocity, or excessive flow depth. These results could dictate the best course of action for a project or prevent a problem from being created. The following figures display the steady-state flow simulations of the 2-year and 10-year storm events.


2-year event

We present these model results with a few caveats: 1) our channel bathymetry data were based on only two measured cross-sections. We compared these cross-sections with the LiDAR-derived channel elevations to determine how much lower the stream bed was relative to top of bank compared with the LiDAR, and lowered each of the HEC-RAS cross-sections by the same mean offset. The channel-bottom surface was then constructed by interpolation and then merged with the floodplain DEM (cf, Quintero et al., 2021). 2) No barriers were placed between channel and floodplain in the model, resulting in areas of the floodplain showing inundation during the 2-year event, but that may not have water due to a lack of connectivity with the channel. 3) The LiDAR base data predate the development of the over-widened channel north of the north footbridge, where a large mid-channel sand and gravel bar provides bedload storage and low-flow channel definition; as a result, our model velocities and depths north of the footbridge are not representative of existing conditions. 4) Finally, model construction used metric system units, so our results are displayed with those units. Despite these caveats, we find that the depth and velocity results from these models help to interpret and explain patterns in floodplain inundation and along-flow variations in thalweg velocity within our study reach.

The depth results from the 2-year simulation indicates the channel is incised as the flows are still unable to access the floodplain. At the 2-year discharge in a healthy stream, water should be able to access the floodplain to provide flood storage, dissipate energy, and disperse sediments and nutrients. The velocity results indicate some areas of higher streamwise velocity corresponding with downstream changes in slope and width.

10-year event



The 10-year event simulation results show the stream is able to access the floodplain at this stage. There remain a number of hotspots where the model predicts high velocities, particularly where the channel narrows. Several areas correspond to high priority erosional problems that the class identified in field. These are areas that may require additional stabilization to prevent future erosion problems. The model results suggest that since it takes a high stage for the stream to access the floodplain, bank stabilization alone may not be enough. It appears that energy needs to be dissipated more efficiently across the floodplain.

2.5. Assessment of the “1900 reference condition”

Some philosophies of ecological restoration argue that streams should be restored to pre-disturbance conditions. Since there is little record of pre-disturbance conditions in most settings, this is rarely possible. However, the LiDAR hillshade of the wooded floodplain area west of Ioway Creek within Brookside Park reveals a number of different meander scars and old channel segments (Figure 12). The age of these channel scars is unknown, as the earliest available aerial imagery available shows the channel mostly near its present location. Nevertheless, it is instructive to assess whether any of the restoration goals could be accomplished by re-establishing old channel dimensions. Lacking a better term, we have referred to this as the “1900 reference condition”.

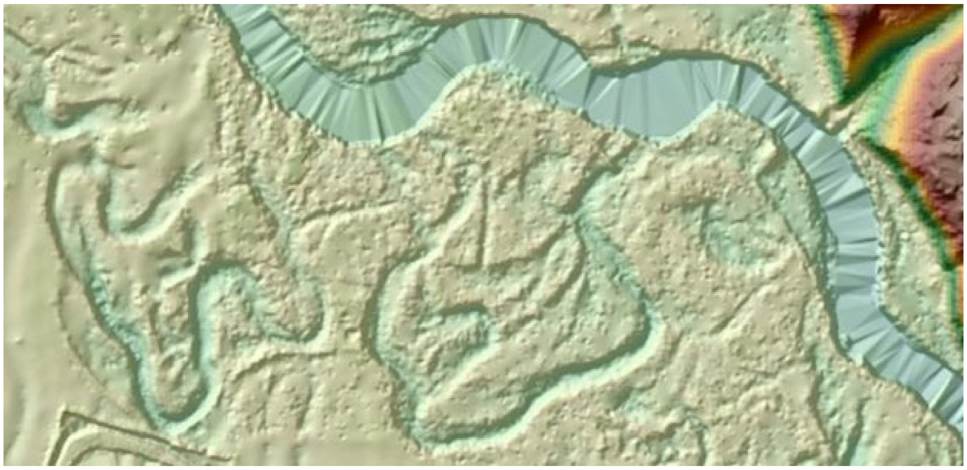


Figure 12. LiDAR color hillshade from the Iowa Geographic Map Server of the northern reach of Ioway Creek and the wooded floodplain in Brookside Park.

At first glance, it's easy to see the 1900 reference channel was much narrower and more sinuous than it is presently, assuming that it occupied a single-thread channel. A more in-depth analysis revealed, using the same bankfull discharge calculation method as before but with dimension and pattern parameters extracted from the channel scars, that the bankfull depth of the historic stream was about 3.3 feet (Figure 13) with a corresponding discharge of approximately 1000 cfs. That discharge would be exceeded on more than 7 days per year according to the current flow duration curve, and would very likely yield an unstable channel if implemented under today’s flow regime.

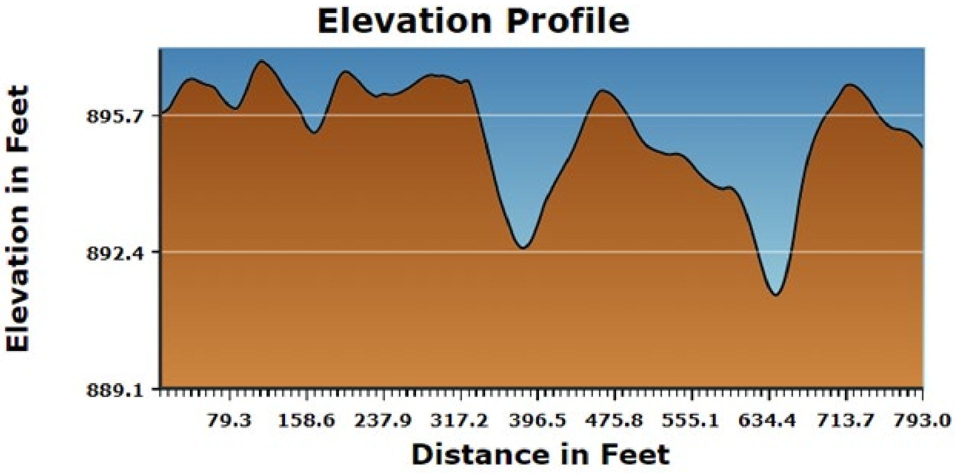


Figure 13: Elevation profile generated using the Iowa DNR elevation profile tool. This cross-section illustrates the pre-1900 channel dimensions of Ioway Creek.

From the elevation cross-section of the old channels, it is easy to see the cross-sectional area is much smaller than present-day Ioway Creek. This form of Ioway Creek represents a different time in terms of hydrologic setting, and replication of this channel form and dimensions would be inadvisable.

3. BIOTIC & WATER QUALITY INDICATORS

3.1. Biotic Assessments

Due to extreme low-water conditions at the time of our surveys, we were unable to do a complete habitat and biotic assessment. For the assessment metrics we sought that required more substantial flow, we resorted to data mining from existing databases.

BioNET, a database of physical habitat and biotic data collected by the State Hygeinic Lab, DNR, and partners, provides useful biotic indices including biotic integrity. A Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI) value of 74 was determined at a site downstream from Brookside Park at Stewart Smith Park in the year 2000. This index value indicated “good” stream health. This index combines several metrics that characterize the number, diversity, and sensitivity to pollution of macroinvertebrate taxa present in the stream.

The ADBNet database provides data on water quality assessments and impairments within the framework of the U.S. Clean Water Act. Ioway Creek is classified as a Class A1 stream with primary contact recreational use (A1: presumptive) and class B warm water 2 (BWW2) aquatic life use. A site a short distance upstream of Brookside was assessed in 2020, and though flow was insufficient to fully evaluate these uses, measurements indicated *e. coli* levels that exceed state criteria.

Brookside Park is also the site of several citizen water quality monitoring sites, including the now-discontinued IOWATER program, and its successor SOS. Many of these data are available from the Clean Water Hub (https://www.cleanwaterhub.org/community) supported by the Izaak Walton

League. In general, the water quality indicators at these sites are consistent with many Iowa streams draining primarily agricultural landscapes: seasonally-high nutrient loads, but a resilient system that returns to fair or good water quality between runoff events. Importantly, few of these citizen-monitoring assessments included indicator bacteria assessments.

3.2. Our Informal Observations

While in the creek in September and October 2021, we observed many of the animals that call Brookside Park and Ioway Creek home. We observed mayfly nymphs, damselfly nymphs, caddis fly larvae, and hellgrammites, as well as mussels. These taxa are bioindicators of stream health and some of them are rare or possibly endangered. Mussel relocation is a common practice for streams undergoing restoration projects that contain endangered mussels. We would recommend a DNR mussel survey to determine if those individuals in Brookside are listed as an endangered species.

Figure 14. An example of some of the taxa encountered in Brookside Park. Specimens in glass containers were collected by one member of our group prior to our study.

3.3. Habitat Assessment

Habitat assessments that we were able to complete despite the poor flow conditions included a large wood inventory, riffle pebble counts, and facet (also known as geomorphic channel units) mapping. We used a simplified large wood tally method with 9 different diameter-length categories to estimate wood volumes within the baseflow (zone I) and bankfull (zone II) channel. We also used data from the EPA's National Rivers and Streams Assessment (NRSA) to provide some context for our results. Expressed in terms of wood volume per 100 meters of stream length, we found approximately 0.24 m^3/100m in our study reach. While this number alone may not be particularly revealing, a comparison with other rivers and streams in the same (temperate plains) ecoregion suggests that this reach has a relatively small wood load (Figure 15).

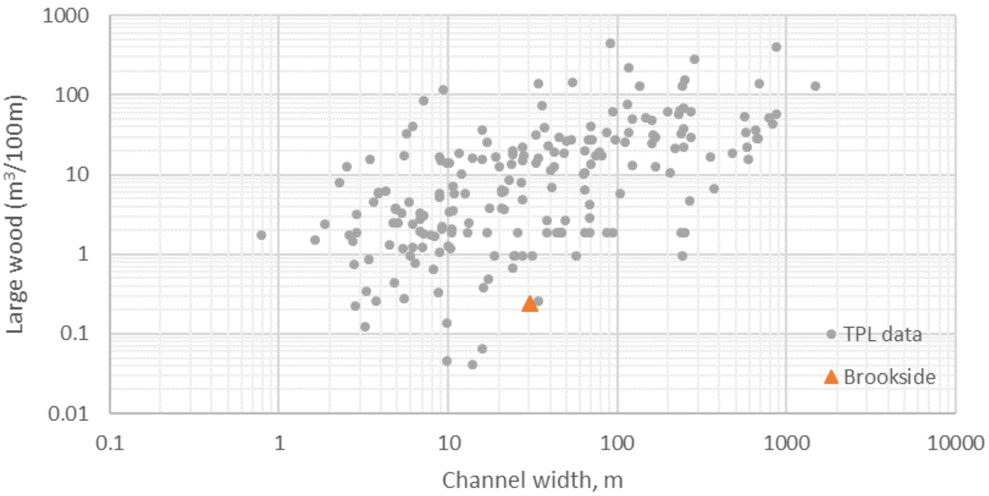


Figure 15. A log-log plot showing large wood volume per channel length as a function of channel width. Brookside large wood data from this study are very low compared with other sites in the region.

Our facet survey was hampered by the low water conditions, but was judged on the basis of bed topography and particle size observations. In general, true riffles and pools were limited due to the relatively straight and simplified channel, and those we identified as pools and riffles were "borderline" cases. In total, we assessed 1600 feet of channel length representing nearly 130,000 ft^2 of bed area, of which more than two-thirds (67.7%) was pool and glide. Facet proportions are similar when expressed in terms of length and area.

Facet Type	Combined Linear Feet	Percentage
Pool	825 ft	50.3%
Riffle	230 ft	14%
Run	300 ft	18.3%
Glide	285 ft	17.4%

Table 1. Approximate distribution of facet types in the habitat survey.

One of the habitat metrics employed in the IRRT is pool-to-pool spacing. Because of the relatively large proportion of channel found to be pool and glide, pool-to-pool spacing is small, estimated to be 270 ft, or less than 3 channel widths.

Bed particle size was measured using the Wolman pebble count method in areas identified as riffles or runs Figure 16. The upstream site was located near station 1+05, which was not a proper riffle but rather a scoured section of bed at the downstream end of the channel constriction below the north footbridge. Particle sizes there included sand and gravel, as well as a small number of cobbles. D_{50} (the median particle size) was roughly 2mm. A second riffle, located downstream at station 10+10, appeared to be a partially constructed riffle, as it was composed of both natural till-derived cobbles and broken concrete arranged across the channel near the downstream end of the till bluff. The D_{50} in this riffle was considerably higher, approximately 24 mm, but these coarser particle sizes were found in relatively few places elsewhere on the bed. Considering these findings, we used the finer D_{50} in analyses related to channel classification and bedload transport. The coarser bed found in the 10+10 riffle is important, however, as it provides a greater degree of vertical channel stability in the only functional riffle within the reach.

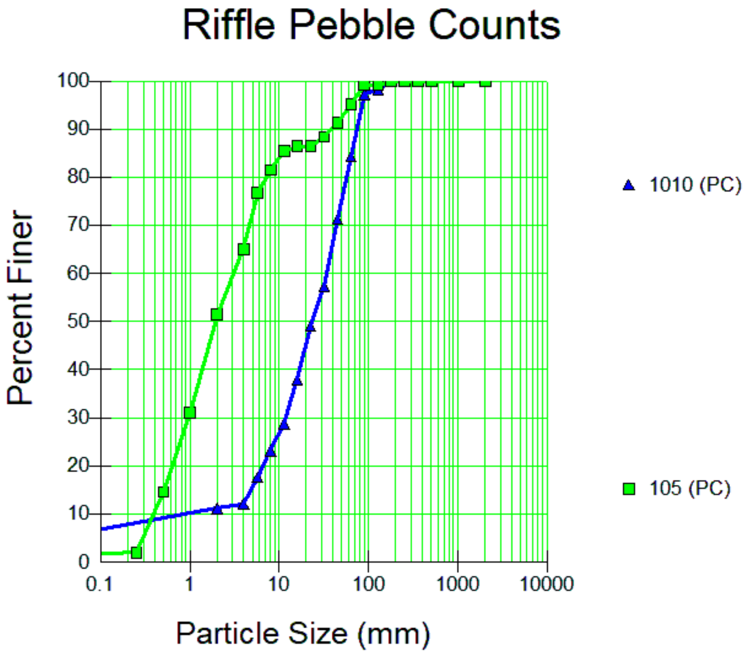
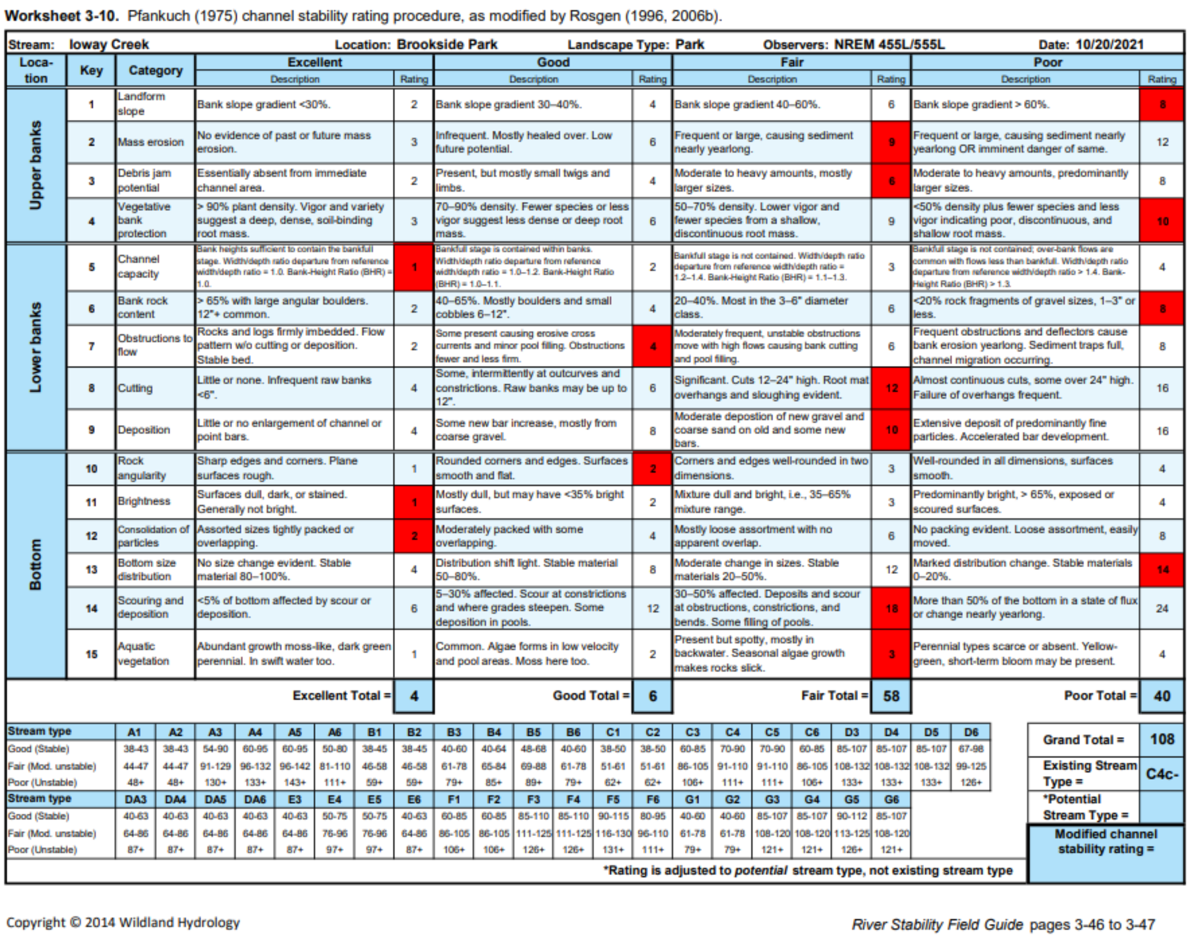


Figure 16. Riffle particle-size distributions from stations 10+10 (green squares) and 1+05 (blue triangles).

4. CHANNEL STABILITY

4.1. Pfankuch Stability Assessment

The Pfankuch Stability Assessment is a qualitative assessment of stream health that relies on visual and subjective observations that can indicate ongoing conditions in the stream. Based upon the ratings measured in the field and the Rosgen stream type, the channel classified as "Fair, moderately unstable." Figure 17 shows the specific ratings given. It should be noted that this rating system was not designed for use in Midwestern streams, and are more representative for Mountain streams. However, this is a quick way to show the relative instability of the system.



Worksheet 3-10. Pfankuch (1975) channel stability rating procedure, as modified by Rosgen (1996, 2006b).

Stream: Ioway Creek **Location:** Brookside Park **Landscape Type:** Park **Observers:** NREM 455L/555L **Date:** 10/20/2021

Location	Key	Category	Excellent Description	Rating	Good Description	Rating	Fair Description	Rating	Poor Description	Rating
Upper banks	1	Landform slope	Bank slope gradient <30%.	2	Bank slope gradient 30–40%.	4	Bank slope gradient 40–60%.	6	Bank slope gradient > 60%.	**8**
	2	Mass erosion	No evidence of past or future mass erosion.	3	Infrequent. Mostly healed over. Low future potential.	6	Frequent or large, causing sediment nearly yearlong.	**9**	Frequent or large, causing sediment nearly yearlong OR imminent danger of same.	12
	3	Debris jam potential	Essentially absent from immediate channel area.	2	Present, but mostly small twigs and limbs.	4	Moderate to heavy amounts, mostly larger sizes.	**6**	Moderate to heavy amounts, predominantly larger sizes.	8
	4	Vegetative bank protection	> 90% plant density. Vigor and variety suggest a deep, dense, soil-binding root mass.	3	70–90% density. Fewer species or less vigor suggest less dense or deep root mass.	6	50–70% density. Lower vigor and fewer species from a shallow, discontinuous root mass.	9	<50% density plus fewer species and less vigor indicating poor, discontinuous, and shallow root mass.	**10**
Lower banks	5	Channel capacity	Bank heights sufficient to contain the bankfull stage. Width/depth ratio departure from reference width/depth ratio = 1.0. Bank-Height Ratio (BHR) = 1.0.	**1**	Bankfull stage is contained within banks. Width/depth ratio departure from reference width/depth ratio = 1.0–1.2. Bank-Height Ratio (BHR) = 1.0–1.1.	2	Bankfull stage is not contained. Width/depth ratio departure from reference width/depth ratio = 1.2–1.4. Bank-Height Ratio (BHR) = 1.1–1.3.	3	Bankfull stage is not contained; over-bank flows are common with flows less than bankfull. Width/depth ratio departure from reference width/depth ratio > 1.4. Bank-Height Ratio (BHR) > 1.3.	4
	6	Bank rock content	> 65% with large angular boulders. 12"+ common.	2	40–65%. Mostly boulders and small cobbles 6–12".	4	20–40%. Most in the 3–6" diameter class.	6	<20% rock fragments of gravel sizes, 1–3" or less.	**8**
	7	Obstructions to flow	Rocks and logs firmly imbedded. Flow pattern w/o cutting or deposition. Stable bed.	2	Some present causing erosive cross currents and minor pool filling. Obstructions fewer and less firm.	**4**	Moderately frequent, unstable obstructions move with high flows causing bank cutting and pool filling.	6	Frequent obstructions and deflectors cause bank erosion yearlong. Sediment traps full, channel migration occurring.	8
	8	Cutting	Little or none. Infrequent raw banks <6".	4	Some, intermittently at outcurves and constrictions. Raw banks may be up to 12".	6	Significant. Cuts 12–24" high. Root mat overhangs and sloughing evident.	**12**	Almost continuous cuts, some over 24" high. Failure of overhangs frequent.	16
	9	Deposition	Little or no enlargement of channel or point bars.	4	Some new bar increase, mostly from coarse gravel.	8	Moderate depostion of new gravel and coarse sand on old and some new bars.	**10**	Extensive deposit of predominantly fine particles. Accelerated bar development.	16
Bottom	10	Rock angularity	Sharp edges and corners. Plane surfaces rough.	1	Rounded corners and edges. Surfaces smooth and flat.	**2**	Corners and edges well-rounded in two dimensions.	3	Well-rounded in all dimensions, surfaces smooth.	4
	11	Brightness	Surfaces dull, dark, or stained. Generally not bright.	**1**	Mostly dull, but may have <35% bright surfaces.	2	Mixture dull and bright, i.e., 35–65% mixture range.	3	Predominantly bright, > 65%, exposed or scoured surfaces.	4
	12	Consolidation of particles	Assorted sizes tightly packed or overlapping.	**2**	Moderately packed with some overlapping.	4	Mostly loose assortment with no apparent overlap.	6	No packing evident. Loose assortment, easily moved.	8
	13	Bottom size distribution	No size change evident. Stable material 80–100%.	4	Distribution shift light. Stable material 50–80%.	8	Moderate change in sizes. Stable materials 20–50%.	12	Marked distribution change. Stable materials 0–20%.	**14**
	14	Scouring and deposition	<5% of bottom affected by scour or deposition.	6	5–30% affected. Scour at constrictions and where grades steepen. Some deposition in pools.	12	30–50% affected. Deposits and scour at obstructions, constrictions, and bends. Some filling of pools.	**18**	More than 50% of the bottom in a state of flux or change nearly yearlong.	24
	15	Aquatic vegetation	Abundant growth moss-like, dark green perennial. In swift water too.	1	Common. Algae forms in low velocity and pool areas. Moss here too.	2	Present but spotty, mostly in backwater. Seasonal algae growth makes rocks slick.	**3**	Perennial types scarce or absent. Yellow-green, short-term bloom may be present.	4
			Excellent Total =	4	Good Total =	6	Fair Total =	58	Poor Total =	40

Stream type	A1	A2	A3	A4	A5	A6	B1	B2	B3	B4	B5	B6	C1	C2	C3	C4	C5	C6	D3	D4	D5	D6
Good (Stable)	38-43	38-43	54-90	60-95	60-95	50-80	38-45	38-45	40-60	40-64	48-68	40-60	38-50	38-50	60-85	70-90	70-90	60-85	85-107	85-107	85-107	67-98
Fair (Mod. unstable)	44-47	44-47	91-129	96-132	96-142	81-110	46-58	46-58	61-78	65-84	69-88	61-78	51-61	51-61	86-105	91-110	91-110	86-105	108-132	108-132	108-132	99-125
Poor (Unstable)	48+	48+	130+	133+	143+	111+	59+	59+	79+	85+	89+	79+	62+	62+	106+	111+	111+	106+	133+	133+	133+	126+

Stream type	DA3	DA4	DA5	DA6	E3	E4	E5	E6	F1	F2	F3	F4	F5	F6	G1	G2	G3	G4	G5	G6
Good (Stable)	40-63	40-63	40-63	40-63	40-63	50-75	50-75	40-63	60-85	60-85	85-110	85-110	90-115	80-95	40-60	40-60	85-107	85-107	90-112	85-107
Fair (Mod. unstable)	64-86	64-86	64-86	64-86	64-86	76-96	76-96	64-86	86-105	86-105	111-125	111-125	116-130	96-110	61-78	61-78	108-120	108-120	113-125	108-120
Poor (Unstable)	87+	87+	87+	87+	87+	97+	97+	87+	106+	106+	126+	126+	131+	111+	79+	79+	121+	121+	126+	121+

Grand Total =	108
Existing Stream Type =	C4c-
*Potential Stream Type =	
Modified channel stability rating =	

*Rating is adjusted to *potential* stream type, not existing stream type

River Stability Field Guide pages 3-46 to 3-47

Figure 17. Completed Pfankuch stability worksheet for the study reach at Brookside Park, showing a rating on the high (poor) end of "Fair" for the C4 stream type.

4.2. Bank erosion assessment

Due to time limitations, bank erosion severity was assessed using an NRCS field method (termed here NRCS98) rather than the BEHI method recommended in the IRRT workflow. In addition to saving time in the field, the NRCS98 method has recently been calibrated against a multi-year dataset of erosion pins in Onion Creek, a tributary to Ioway Creek on the northwest edge of Ames (J.V. Allen et al, unpublished data*). Table 2 shows the relationship between qualitative erosion category and the corresponding mean bank recession rate measured in Onion Creek.

Category	**rate (±SD), ft/yr**
Slight	0.03 (±0.01)
Moderate*	0.17 (±0.12)
Severe*	0.34 (±0.12)
Very Severe*	0.46 (±0.31)

Table 2. Approximate erosion rates corresponding to NRCS98 qualitative bank erosion severity categories. Calibration* comes from unpublished data on nearby Onion Creek, and should not be used in other settings until that study is validated and published.

Bank erosion was assessed based on criteria including bank slope, vegetation cover, and overhang conditions to determine overall condition on a qualitative scale from Slight erosion to Very Severe Erosion. Overall, 950 feet of bank was observed to be in “Very Severe” condition, 1210 feet was observed to be in “Severe” condition, 150 feet was observed to be in “Moderate” condition, and the remainder was observed to have “Slight” erosion severity. Based on the type of soil that makes up the bank and the severity of erosion, a volume of sediment supply from bank erosion and slumping can be calculated. That rate of recession and calculation of sediment volume is described below.

4.3. Capacity-Supply Ratio (CSR)

A complete analysis of geomorphic channel stability aligned with the IRRT would require detailed field measurements in an upstream supply reach, as well as the use of modeling tools FLOWSED and POWERSED to estimate a duration-weighted sediment transport capacity for bedload and suspended load. Due to our limited group size and time constraints, we were unable to do more than a rapid qualitative assessment of the upstream supply reach (here, considered to be from 13th Street to the north footbridge). Proper use of FLOWSED and POWERSED also requires region-specific data on bedload sediment transport as well as at least one measurement of bedload transport at bankfull conditions on the study stream. Because Iowa still lacks a robust bedload dataset, the applicability of any model predictions from these methods is uncertain. We therefore took a simpler approach to assessing channel stability on the basis of sediment. We estimated transport capacity of a representative bedload particle size using a simple semi-empirical model and integrating transport over the distribution of flow durations. We then compared this capacity with the size of the in-reach supply from bank erosion estimated above by constructing a simple ratio between capacity and supply (Copeland et al., 1994).

Capacity-Supply Ratio (CSR) is based upon the total influx of sediment and the total sediment carrying capacity of Ioway Creek. The Meyer-Peter and Muller transport equation $q^* = 4(\tau^* - \tau_c^*)^{2/3}$ was rewritten in a dimensional form that incorporates Manning flow resistance and idealized trapezoidal channel geometry. Below is the form of the equation used to determine sediment capacity as a function of both the representative (D_{50}) grain size and discharge.

$$Q_s = 16 w_0 D^{3/2} \left[\left(\frac{nQ}{A} \right)^2 \frac{1}{1.65 D R^{1/3}} - \tau_c^* \right]^{3/2}$$

Once the sediment carrying capacity was calculated for each bin in a discrete discharge distribution, those results were multiplied by the frequency of the flows they were associated with. Streams do not spend most of their time at high discharges, so the duration of those capacities was considered. The CSR could then be estimated based upon influx of sediment into the reach from in-reach erosion and upstream sources. Simply put, CSR is just duration-weighted capacity divided by supply. A ratio of 1 is a system in equilibrium, greater than one is a system that risks incision, and less than one is a sign of an aggrading channel with ample sediment supply. Ioway Creek had a calculated duration-weighted sediment transport capacity of 50,000 pounds per year. Minimum sediment influx into the reach is calculated at 615,000 pounds per year. Consequently, the calculated CSR for Ioway Creek was 0.08. For the calculation of sediment transport capacity, D_{50} grain size was used. That is likely larger than the most abundant grain size transported in channel forming flows, so this represents a conservatively-low capacity estimate. However, even with a gain-size-weighted computation, the capacity would still likely be much smaller than supply.

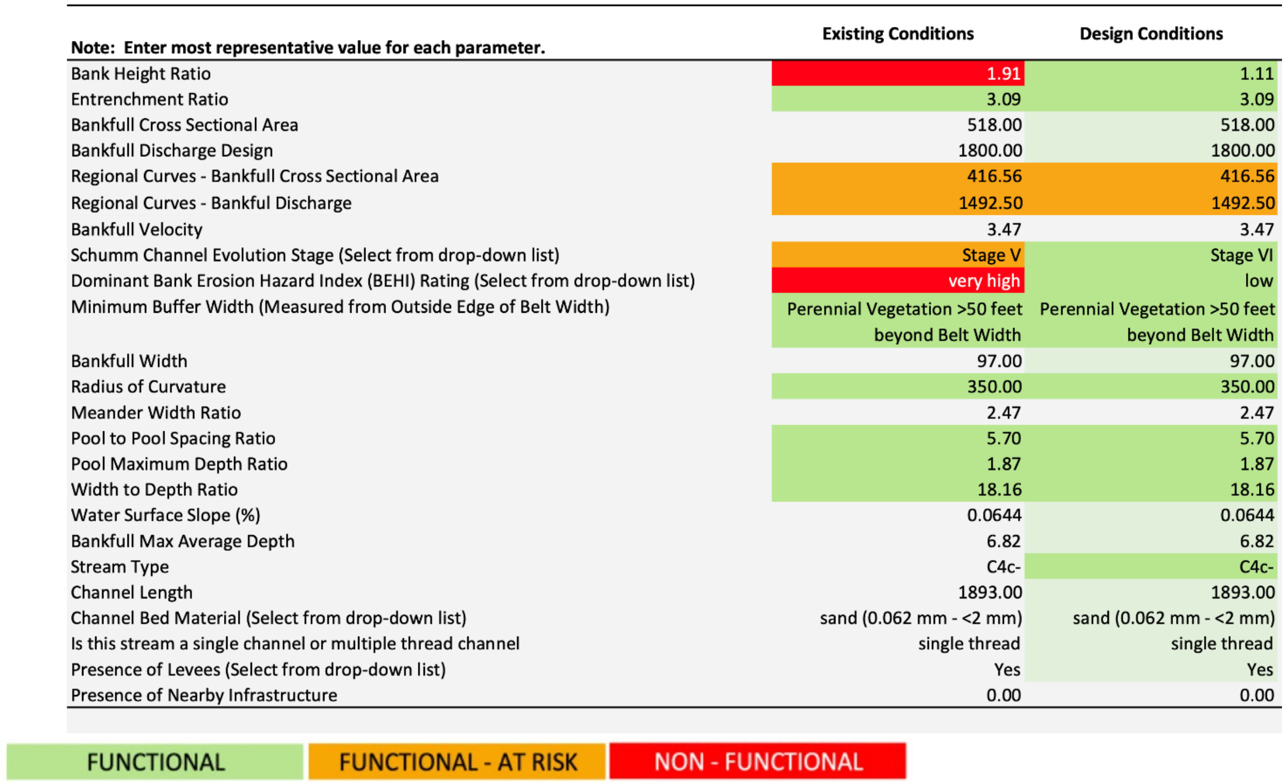
5. IOWA RIVER RESTORATION TOOLBOX ASSESSMENT

5.1. Existing conditions evaluation

Table 3 shows existing stream conditions surveyed by our group that were included as parameters in the Iowa River Restoration Toolbox assessment. These include the median grain size (D_{50}), channel sinuosity, channel evolution stage, dominant depositional pattern, valley confinement, and pool-to-pool spacing, among other parameters.

Parameters		Parameters		Parameters	
Drainage area:	204 mi^2	Bankfull depth:	5.3 feet	Sinuosity:	1.15
Region:	Des Moines Lobe	Pool-pool spacing:	270 feet	Channel slope:	0.0663%
Flow regime:	Perennial	Belt width:	240 feet	Width-depth ratio;	18.3
Confinement:	Partly confined	Bank material:	Silt/clay	Entrenchment R:	> 3.09
Bankfull width:	97 feet	Bankful discharge:	1492 cfs	Bank height ratio:	1.91
Levee presence:	No	D50:	16 mm	Pool-depth ratio:	1.51
Meander pattern:	Truncated meander	Radius of Curv.:	> 350 ft	Bed material:	Fine Gravel
Banks w/ veg.:	20-40%	Fish IBI:	51	Channel evo. stage:	V

Table 3. Table of Iowa River Restoration Toolbox parameters.



Note: Enter most representative value for each parameter.	**Existing Conditions**	**Design Conditions**
Bank Height Ratio	1.91	1.11
Entrenchment Ratio	3.09	3.09
Bankfull Cross Sectional Area	518.00	518.00
Bankfull Discharge Design	1800.00	1800.00
Regional Curves - Bankfull Cross Sectional Area	416.56	416.56
Regional Curves - Bankful Discharge	1492.50	1492.50
Bankfull Velocity	3.47	3.47
Schumm Channel Evolution Stage (Select from drop-down list)	Stage V	Stage VI
Dominant Bank Erosion Hazard Index (BEHI) Rating (Select from drop-down list)	very high	low
Minimum Buffer Width (Measured from Outside Edge of Belt Width)	Perennial Vegetation >50 feet beyond Belt Width	Perennial Vegetation >50 feet beyond Belt Width
Bankfull Width	97.00	97.00
Radius of Curvature	350.00	350.00
Meander Width Ratio	2.47	2.47
Pool to Pool Spacing Ratio	5.70	5.70
Pool Maximum Depth Ratio	1.87	1.87
Width to Depth Ratio	18.16	18.16
Water Surface Slope (%)	0.0644	0.0644
Bankfull Max Average Depth	6.82	6.82
Stream Type	C4c-	C4c-
Channel Length	1893.00	1893.00
Channel Bed Material (Select from drop-down list)	sand (0.062 mm - <2 mm)	sand (0.062 mm - <2 mm)
Is this stream a single channel or multiple thread channel	single thread	single thread
Presence of Levees (Select from drop-down list)	Yes	Yes
Presence of Nearby Infrastructure	0.00	0.00

Figure 18. Screenshot of the IRRT Design tab, which identifies key parameters as Functional, Functional-at risk, or Non-functional with color coding in the Existing Conditions column. Design conditions shown here are arbitrary, and do not necessarily represent recommended design elements.

5.2. Technique ranking results

Based on these inputs, the IRRT has produced a tiered list of restoration techniques aimed at improving stream metrics that have been categorized as at-risk or non-functional. These techniques are categorized according to practice and discussed below, regardless of whether we deem them appropriate.

With regard to grade control, the IRRT has recognized two workable techniques that will help mitigate the poor bank-height-ratio (over-steepened banks), should grade control be deemed necessary. Listed in order of increasing likelihood of success, these techniques are rock and log riffles and rock constructed riffles. The reason the rock-and-log riffle is less feasible in this setting pertains to the high width of the channel at Brookside. A rock-and-log riffle is designed to deflect the thalweg away from a degrading bank to curtail erosion. This requires a sufficiently long log, capable of extending across the channel and keyed for stability into the bank. Finding a sufficiently long log would be difficult in the region. The preferred option would be to construct a rock riffle. This is a control structure aimed at reducing stream grade and thereby remove some of the erosive potential downstream. These structures also benefit aquatic organisms as they provide a means of oxygenating the water.

Regarding vegetation and riparian buffering in the reach, nearly any recognized approach would be effective. To establish native vegetation for bank stabilization, any of the following techniques could be used to equal effect: live staking, joint planting, lives fascines, brush layering, and erosion or sod matting. To enhance the riparian buffer, any means of establishing and preserving native species is sufficient.

To restore banks and floodplains, the IRRT suggests bank sloping, multistage channeling, or oxbow establishment. Concerning bank grading, the toolbox suggests this is less viable than the alternatives, a consequence of the length of the reach. However, the alternatives are more costly. Establishing an oxbow or a multistage channel also requires a significant amount of earth moving. Thus, grading banks should be held as the most appropriate technique in this case, though it is recommended that grading avoid removal of desirable mature trees in the area.

To maintain or improve aquatic habitat the best chance of success, and most affordable option, would result from imbedding boulders/rock clusters in the channel for fish rest/hold habitat in the swift water. Logs or LUNKERS could also be used at higher cost and similar effect.

More importantly, to stabilize the at-risk bank IRRT suggests toe wood, stone toe protection, vegetating banks, or fabric encapsulated soil lifts would be most effective. Toe wood technique involves anchoring logs into a bank toe with root wads directed outward towards the channel. Toe wood adds surface roughness to slow the flow of water as well as deflect the thalweg away from the bank. Stone toe protection could also be implemented cheaply with local quarry stone; however, its effectiveness is questionable in many cases. Whichever bank stabilization technique is used issued, vegetating the bank afterwards ought to be top priority to reduce further degradation. More advanced methods, such as the placement of encapsulated soil lifts, could also be effective.

Any channel definition structure, such as J-hooks, weirs, or stream barbs, could be implemented where thalweg steering is a necessary component of design. Some techniques (such as engineered log jams) may increase flood risk and should therefore be considered unwise. However, those that result in little added flow resistance (like J-hooks) may assist with maintaining stable bends in a re-aligned channel.

6. STAKEHOLDER INPUT

6.1. Impacted landowners

Several properties between Ioway Creek and Brookridge Avenue are currently at risk (Figure 19). The primary concern of these property owners is the slope erosion occurring on the till bluff. If nothing is done to mitigate further bluff recession, these landowners will continue losing property and, for one property owner, they risk losing a structure to the retreating slope within the next decade. However, for others, they risk losing garden space and landscaped yard area that they have worked hard to maintain. The affected property owners purchased this land with the expectation that the city could, at the very least, maintain their property lines and take action to ensure their land is not threatened by forces outside their control.

Figure 19. Map showing three residential properties that are significantly affected by erosion along the till bluff.

6.2. Park users/visitors

The city's plans to act on the Brookside Park project have drawn great interest amongst the people of Ames. This is a clear indication that many in Ames would hope to see Brookside Park remain a fun and safe park for everyone in the city. When engaging with some of these park users, it is apparent that many have concerns about which direction should be taken aesthetically, and functionally, for the Brookside project. Community leaders that were questioned expressed a hope that developers would make maintaining the natural aesthetic of the park a top priority, as well as act to keep walking paths accessible during the development. Moreover, patrons of the park are asking for safer, easier access down to the channel, with the hope that this access could be integrated into the natural aesthetic of the park without appearing too grand or artificial. A key concern among some well-informed park-users and neighborhood residents is the stabilization of the east bank. One of the affected residents we spoke to had lived on the east bank for nearly 30 years and had commented on the worsening slope erosion that they had observed during their stay. They recognized the need for immediate action or face the risk of losing infrastructure soon.

The group known as Friends of Brookside Park has also discussed concern over the possible infestation of invasive plants following ground disturbance resulting from the development process. All stakeholders are also concerned about flooding potential post-development, whereby allowing the channel access to more of its floodplain may affect recreation potential in the park and may make parts of it inaccessible for some parts of the year.

Currently the park is used by many Ames residents. Locals frequent the park for social gatherings, sports, tranquil walks, picnics, and fishing. Some residents have also described winter activities they enjoy there, such as country skiing on the channel. Many residents choose to bring their pets to the park for exercise and leisure. Some even bring their pets to socialize or meet other pets (this writer included, for both a pet dog and pet cat). Student residents often choose to spend time at the park as a relaxing break from their studies. During the ongoing COVID-19 pandemic, gatherings at this park have proven to be especially important for Ames organizations and residents in boosting morale and supporting continued socialization aligned with current safety recommendations.

7. RECOMMENDATIONS

In this section, we summarize key findings from our study, highlight problems that could be addressed or corrected through restoration activities, and arrive at a list of project goals to guide restoration. We then describe some ideas for design elements and suggest alternatives for incorporating these elements into a restoration project that addresses these goals.

7.1. Summary of key threats & opportunities

One of the most puzzling and consequential features of the study reach in Brookside is the concrete-armored bank on river-right, between stations 6+00 and 7+00 (Figure 3). Given its position upstream from and opposite the problematic till bluff, we believe this bank armor exacerbates the bluff erosion problem by focusing flow energy into the river-left bank at the toe of the bluff. Through exploration of city utility maps and discussion with knowledgeable city staff, we have discerned no current or future infrastructure whose protection would necessitate preservation of this armor or the existing position of this bank. There is consequently an opportunity to remove a stressor from the system by dismantling this armor.

While addressing the armored bank may remove a stressor, it cannot alone prevent erosion of the till bluff or any other steep, eroding banks in the reach. Reduction in recession rate could be accomplished throughout the reach by regrading or stabilizing problematic banks. This should, however, be understood to affect the sediment budget of the reach, and if in-reach sediment inputs are reduced drastically, the reach could switch from aggrading to degrading once again.

As indicated earlier, we don’t see evidence that Ioway Creek is actively degrading within the reach. It appears that the upstream reach above the north footbridge generates abundant sediment supply through bank erosion and slumping, storing much within the bankfull channel there as bars and sand sheets. Some portion of the coarse fraction of that sediment undoubtedly passes through the constriction beneath the footbridge and is stored on the bed in a mid-channel flow-expansion bar there, though this feature is likely transient. With additional distance downstream, the widening channel and concentrated bank erosion introduces enough coarse sediment to provide excess supply to the reach. Thus, there doesn’t currently seem to be a need for grade control beyond the existing structure downstream of the south footbridge.

Nevertheless, past channel incision disconnected the creek from the floodplain in the study reach, resulting in floodplain inundation apparently less frequent than every 2 years. In non-urban settings, floodplain reconnection can sometimes be a major goal of restoration projects, but given the urban setting and the many park amenities and private properties nearby and downstream, any restoration efforts in this reach should avoid raising flood stages as a means of floodplain reconnection. An alternative approach, though it typically connects much smaller areas of conveyance, is to construct bankfull benches within the channel belt where flows can spread out onto low, vegetated floodplain areas without inundating park infrastructure.

While the broken-concrete grade control structure downstream of the south footbridge seems to be effective, it is not attractive and could be replaced or augmented with quarry stone. We infer that this structure was intended to protect the city water supply to the park, so grade control is warranted there. Partial replacement of this structure could improve aesthetics and could also represent an opportunity to incorporate public access elements, given the proximity of this structure to the parking area and 6th Street bridge.

7.2. Summary of recommended goals

Considering these problems and opportunities, we have identified some proposed project goals that can guide design decisions. The first three of these are considered to be top priority goals:

1. Protect landowner property from erosion and land loss.
2. Maintain or improve lateral and vertical channel stability.
3. Maintain or improve public access to the river through the park.

In addition, we have identified four more goals that could improve the ecosystem services provided by a restored creek:

4. Maintain or improve aesthetic/natural character of the park: the park currently has a nice combination of managed greenspace and more natural bottomland forest.
5. Reduce or avoid exacerbating flood hazard through the Ioway creek corridor.
6. Maintain or improve habitat for fish and wildlife that live in or use the park and or creek: this could include saving and protecting mature trees, making sure habitat for wildlife is not lost during project implementation, and creating more diverse habitats in the stream.
7. Maintain or improve water quality

7.3. Design concept

Rather than specifying a single restoration concept, we provide some possible design elements that can be combined or substituted. In the section that follows, three alternatives that combine different elements are offered. A schematic diagram of a portion of these alternatives is given in Figure 19.

a. Remove problematic riprap between stations 6+00 and 7+00 on the right bank
b. Regrade & vegetate banks where feasible, while preserving desirable trees
c. Flow deflection and toe protection along bluff toe
d. Channel definition structures on problematic bends (J-hooks, cutoff sills, barbs)
e. Flatten bend across from bluff, shifting ~400 feet of channel 50-100 feet west at bend apex; build out bankfull bench at the foot of the bluff slope
f. Re-route 800 feet channel through a floodplain channel scar; retain but stabilize the derelict channel at inlet/outlet as stormwater treatment pond/oxbow; re-grade floodplain remnant to a bankfull bench

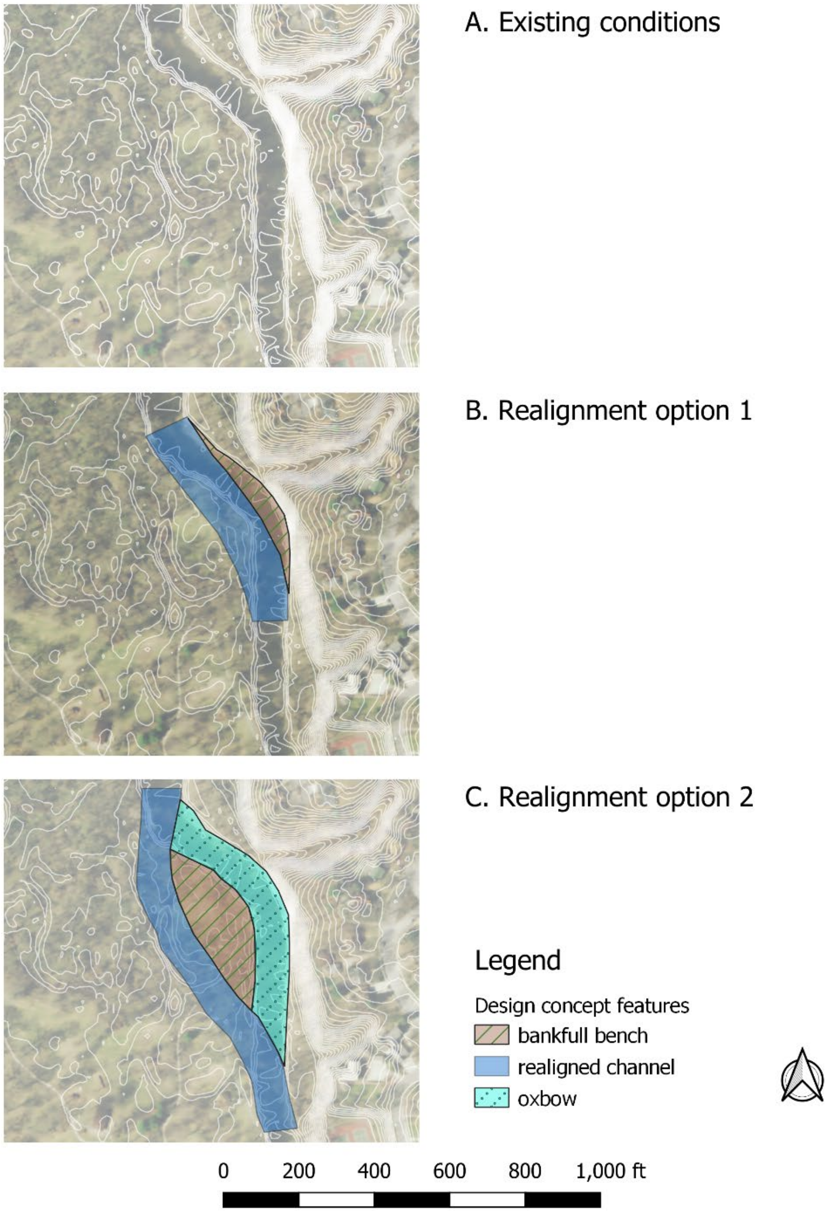


Figure 20. Existing conditions and two possible channel realignment scenarios for the channel segment along and upstream from the till bluff.

Alternative 1: Stressor Removal without Channel Realignment

- (a) Remove problematic riprap
- (c) Deflect flow away from the bluff with barbs or J-hooks on the left bank; protect the bluff toe with a cutoff sill series that promotes sediment accretion along the left bank
- (b) Regrade and vegetate select banks within the reach

Alternative 2: Realignment Option 1

- (a) and (b)
- (e) Construct a bankfull bench on the left bank while realigning the channel from stations 6+00 to 10+00 (Realignment option 1 in Figure 20)

Alternative 3: Realignment Option 2

- (a) and (b)
- (f) Major channel re-alignment from stations 4+00 to 12+00 to re-occupy an old channel scar on the floodplain; establishment of an oxbow in the abandoned channel scar with opportunity for storm water treatment; creation of bankfull bench in the “island” area between abandoned and realigned channel (Realignment option 2 in Figure 20)
- (c) definition of channel thalweg at new bends with barbs or J-hooks

Each of these alternatives addresses Goals 1 and 2 from the list above. While none of them explicitly includes improved public access, graded banks can provide safer access on gentler, more stable bank slopes. The addition of a graded approach to a re-built grade control structure below the south footbridge would help to address Goal 3. Each alternative can also allow for addressing Goals 4-6 through proper design. However, only Alternative 3 addresses Goal 7. Alternative 3 would likely require relocation of a portion of the multi-use path and possibly one picnic shelter.

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