Monitoring Streamflow by Using Video Cameras

By

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PROBLEM STATEMENT

Stream velocity information is critical for triggering site visits or other action by Montana Department of Transportation (MDT) personnel for scour-critical bridges in response to floods. Large-scale Particle Image Velocimetry (LSPIV) installations might provide valuable data for MDT's Plans of Action (POAs) for such sites. LSPIV installations also could provide data on ice jam formation and break-up, and on debris buildup at bridges.

LSPIV installations include a video camera, surveyed reference marks, and small computer. LSPIV installations can provide stream velocity information and, when used along with channel cross sections and other field data, stream discharge data. But LSPIV is relatively new, and the U.S. Geological Survey (USGS) is just beginning to test the technology in select locations across the United States.

BACKGROUND SUMMARY

The USGS is exploring the use of LSPIV to obtain measurements of surface velocities in rivers. For LSPIV, a video camera records images of particles traveling along the stream surface and surface velocities are calculated from those images. LSPIV could be used to measure magnitudes and angles of surface velocities for bridge scour assessments and calculations, for model calibration, or for other hydraulic studies.

The USGS is testing LSPIV devices across the United States. The USGS WY-MT Water Science Center recently installed one LSPIV on the Little Blackfoot River in Montana (fig. 1).

Figure 1. Photograph showing Large Scale Particle Image Velocimetry installation at the Little Blackfoot River near Garrison, Montana.

BENEFITS

LSPIV could be used to measure surface velocity magnitude and angle of attack at bridge piers for various discharges and might help improve pier-scour estimates. LSPIV images might help detect

changes in the channel thalweg that could reflect changes in flow conditions at a bridge pier. LSPIV data also might be useful for identifying "trigger" events used in MDT's Plans of Action (POAs) for scour-critical bridges.

Therefore, this project could help to meet MDT's emphases for safety, cost effectiveness, and sensitivity to the environment.

OBJECTIVES

The objectives of this project are:

1. To investigate the effectiveness and limitations of LSPIV for measuring velocity magnitude and direction related to bridge scour, for detecting changes in a channel thalweg, for POAs for scour-critical bridges and for bridge scour modeling and assessment

2. To investigate the potential for providing real-time information from LSPIV installations using

    a. Live-stream video, or

    b. Periodic photographs or data delivery;

3. To investigate best practices for data processing and distribution, especially for transferring data from the sites to both USGS and MDT personnel.

RESEARCH PLAN

The research plan for the proposed project includes the following major tasks:

Task 1. Select 3-4 sites for installation and operation of LSPIV equipment.

USGS will work with MDT Hydraulics Engineers to select 3-4 USGS streamgage sites for LSPIV installation. Ideally, sites will be easy to access and close to Helena, and all or most of the sites will be at MDT bridges where pier-scour data are being collected. Selection criteria include the following elements:

1. Bridge scour site; preferably one where scour rods and transducers have been installed or where cross section data are collected during or close to high flows
2. Streamgage (preferably near site, with little or no intervening drainage area)
3. Cellular coverage (available at most streamgages)
4. Access
5. Power (most streamgages equipped with solar panels)
6. Safety (ability to safely work on bridge, traffic considerations)
7. Security (vandalism can be a problem in towns/populated areas)
8. Permitting and right-of way ("local" bridges might require additional permissions)
9. General suitability for LSPIV equipment installation (such as ability to attach camera to structure, existing housing for battery and computer, etc.)

A list of potential candidate sites is included in Table 1.

Table 1. Potential LSPIV Candidate Sites

[1]MDT Hyd Ref. No.	MDT ID	NBIS ID	Stream	Location	NBIS Item 113 Rating	[4]Group	MDT Hydraulics Priority	USGS Streamgage ID	USGS Structures	Notes
186	5392	[3]P00013093+06931	Jefferson River	2M W Three Forks	7	2	Yes	[6]06036650	Walk-in gage house	Thalweg shift concern, less traffic
39	1624	[3]I00090333+05521	Yellowstone River	Livingston	7	2	Yes	[9]06192500	Walk-in gage house and Hoffman-type box for radar.	Thalweg shift concern, traffic concern, 2 transducers (US nose EB, DS WB), Hoffman box/RADAR at EB I90 bridge & walk-in gage house at bridges, not surveying cross section. Walk-in gage house for gage located at Carter Bridge.
	1625	I00090333+05522								
3	1560	[3]I00090278+08571	Madison River	1M E Three Forks	7	2	Yes	[7]06041000	Walk-in gaged house	Additional details are on file in the USGS gaging station descriptions located on file at the WY-MT WSC
	1561	I00090278+08572								
45	5891	[3]P00049027+05411	Beaverhead River	Twin Bridges	7	2	Yes	[6]06018500	Walk-in gage house	Additional details are on file in the USGS gaging station descriptions located on file at the WY-MT WSC
22	3733	[3]L32210001+00801	Clark Fork	4M SE Bonner/Turah	7	2	Yes	[6]12334550	Walk-in gage house	
216	6719	[2]S00359002+02661	Jefferson River	Jefferson Island	3	1		[8]06026500	5 ft x 5 ft wooden shelter	Additional details are on file in the USGS gaging station descriptions located on file at the WY-MT WSC
181	5902	[3]P00050032+07581	West Gallatin River	17M SE Big Sky	7	2		[8]06043500	Walk-in gage house.	
625	4506	[3]L49001000+08001	Yellowstone River	S Greycliff	7	2		[8]06192500	Walk-in gage house.	Additional details are on file in the USGS gaging station descriptions located on file at the WY-MT WSC
223	5893	[2]P00050007+05621	Cougar Creek	7M N West Yellowstone	3	1		No gage on stream	NA	
279	5208	[2]P00004042+04541	Rock Creek	Fort Rockvale	3	1		[8]06209500	4 ft x 4 ft wooden shelter.	Additional details are on file in the USGS gaging station descriptions located on file at the WY-MT WSC
577	6708	[2]S00347003+04001	West Gallatin River	3M SW Belgrade	3	1		[8]06043500	Walk-in gage house.	
681	6703	[2]S00346006+00001	East Gallatin River	5M E Manhattan	4	1		[7]06048650	Walk-in gage house.	Gage house details are for USGS gage no. 06048700. No description for 06048650.
47	6732	[3]S00370000+05361	Bitterroot River	2M NE Victor	7	2		[6]12350250	Walk-in gage house	Additional details are on file in the USGS gaging station descriptions located on file at the WY-MT WSC
77	5294	[3]P00007043+06661	Bitterroot River	3M S Hamilton	7	2		[8]12344000	Walk-in gage house	
92	6211	[5]P00081024+09621	Judith River	11 M SE Denton	3	1		[8]06110020	??	Additional details are on file in the USGS gaging station descriptions located on file at the WY-MT WSC
97	6618	[5]S00300000+02001	Musselshell River	Ryegate	3	1		[7]06123030	??	
67	5200	[3]P00003101+08001	Two Medicine River	11M SE Browning	7	2		[7]06091700	??	Additional details are on file in the USGS gaging station descriptions located on file at the WY-MT WSC
23	1581	[5]I00090292+04251	Gallatin River	4M SE Manhattan	3	1		[8]06043500	Walk-in gage house.	
	1582	I00090292+04252								Additional details are on file in the USGS gaging station descriptions located on file at the WY-MT WSC
180	6377	[3]S00205014+05181	West Gallatin River	4M SE Manhattan	7	2		'806043500	Walk-in gage house.	
New sites being monitored since FY2017										
179	6376	[3]S00205013+00791	Baker Creek	2M SE Manhattan	7	2		No gage on stream	NA	Additional details are on file in the USGS gaging station descriptions located on file at the WY-MT WSC
52	6736	[2]S00373000+04001	Bitterroot River	Woodside	3	1		[8]12344000	??	

Acronyms: MDT - Montana Department of Transportation,
NBIS ID - National Bridge Inventory Standards identification number

Superscripts: [1]Reference number from MDT Hydraulics section tracking of scour evaluation.

[2]Bridge was rated by MDT to be scour critical and scour countermeasures have not yet been installed (NBI rating = 3).

[2]Bridge was rated by MDT to be scour critical and scour countermeasures have been installed (NBIS rating = 3), so the bridge is no longer considered scour critical.

[3]Bridge was rated by MDT to not be scour critical (NBIS rating = 4 or 5), but MDT seeks to monitor performance of scour countermeasures (grout-filled bags) that were installed.

[4]Group number is based on whether bridge is considered scour critical (Group 1) or not scour critical (Group 2).]

[5]Scour Countermeasures have failed – bridge is scour critical

[6] Streamgage is at or very close to bridge

[7] Streamgage is some distance from bridge, with minor to modest intervening DA

[8] Streamgage is some distance from bridge, with substantial intervening DA

[9] Streamgage is some distance from bridge and flow is divided between an east and west channel.

Task 2. Install and operate LSPIV equipment.

USGS staff will install and operate LSPIV equipment per the *draft guidelines* published by the USGS Office of Surface Water (OSW) Surface Velocity Workgroup. Peak stage and surface velocity values will be obtained and documented during periodic site inspections at 3-4 LSPIV gaging stations. Four control points will be surveyed for video rectification.

Task 3. Download and process LSPIV data.

USGS staff will download and process LSPIV data using PIVLab or PTVlab, RIVeR software or other suitable packages, per instructions documented in the USGS *draft guidelines*. Upon completion of field data collection in 2019-2020, data will be compiled and quality assured.

Task 4. Distribute and Publish data

USGS staff will investigate the potential for publishing velocities on *USGS National Water Information System* (NWIS) or other outlets such as *USGS ScienceBase*. Access by MDT staff to data prior to publication also will be explored, as well as necessary training if MDT staff plan to process the data.

Task 5. Evaluate Data

LSPIV velocity data will be evaluated for measuring magnitude and direction of velocities at bridges, for detecting changes to the thalweg that could reflect changes in flow conditions at a pier, for bridge scour assessment and modeling, and for detection of debris on bridge piers. We will compare LSPIV measurements with measurements using an Acoustic Doppler Current Profiler (ADCP) or other equipment.

Task 6. Additional questions – data delivery

USGS staff will work with MDT staff to explore options for real-time data delivery. The USGS GOES system used to transmit USGS streamgage data likely does not have the capacity to transmit large video streams. We will explore the use of cellular networks, iridium technology, or MDT networks that serve webcam images. Other 2-way communication options also will be investigated.

MDT INVOLVEMENT

USGS staff will purchase necessary equipment, and conduct the equipment installation and operation and data processing work. USGS staff will work with MDT hydraulics staff on site selection, data access, publishing, and real-time issues. USGS will coordinate with MDT on access and encroachment permits for the equipment, as necessary. USGS also might coordinate with MDT Information Technology staff regarding MDT webcams and other data infrastructure.

Per USGS publishing requirements and MDT research policies, USGS will submit draft documents to the MDT Research Project Manager at least two months prior to the project end date to provide sufficient time for review and revision.

PRODUCTS

The proposed study will produce the following:

- Quarterly progress reports
- Presentation after end of first year and second year of project
- Fact Sheet, Story Map, or Data Release documenting the research tasks and results
- Conference presentation

IMPLEMENTATION

The results of the proposed project will further knowledge of the effectiveness and limitations of LSPIV installations for assessing flow conditions at piers, for detecting channel thalweg changes that might change flow conditions at piers, for providing data for “triggers” for POAs at scour-critical bridges, and for bridge scour modeling and assessment.

PROJECT SCHEDULE

Table 2. Project Schedule, Federal Fiscal Year (FFY) 2019, State Fiscal Year (SFY) 2019 – 2020

	FFY 2019											
	SFY 2019									SFY 2020		
Task	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept
Project Begins											X	
1. Select sites											X	
2. a. Install LSPIV equipment												X
2. b. Operate LSPIV equipment												X
3. Download and process data												X
4. Distribute and publish data												
5. Evaluate data												
6. Fact sheet or story map												

Table 3. Project Schedule, Federal Fiscal Year 2020, State Fiscal Year 2020 – 2021

	FFY 2020											
	SFY 2020									SFY 2021		
Task	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept
Project Begins												
1. Select sites												
2. a. Install LSPIV equipment	X	X						X	X	X	X	
2. b. Operate LSPIV equipment	X	X	X	X	X	X	X	X	X	X	X	X
3. Download and process data	X	X	X	X	X	X	X	X	X	X	X	X
4. Distribute and publish data												
5. Evaluate data								X	X	X	X	X
6. Fact sheet or story map												

Table 4. Project Schedule, Federal Fiscal Year 2021, State Fiscal Year 2021 – 2022

	FFY 2021											
	SFY 2021									SFY 2022		
Task	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept
Project Begins												
1. Select sites												
2. a. Install LSPIV equipment												
2. b. Operate LSPIV equipment	X											
3. Download and process data	X	X	X	X								
4. Distribute and publish data	X	X	X	X	X	X	X	X				
5. Evaluate data	X	X	X	X	X	X	X	X	X			
6. Fact sheet or story map - writing					X	X	X	X	X	X		
7. Fact sheet or story map – review (USGS colleague reviews and MDT review) and revisions.										X	X	X
8. Fact sheet or story map – online publication											X	X

Table 5. Project Schedule, Federal Fiscal Year 2022, State Fiscal Year 2022

	FFY 2022											
	SFY 2022									SFY 2023		
Task	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept
Project Begins												
1. Select sites												
2. a. Install LSPIV equipment												
2. b. Operate LSPIV equipment												
3. Download and process data												
4. Distribute and publish data												
5. Evaluate data												
6. Fact sheet or story map - writing												
7. Fact sheet or story map – review (USGS colleague reviews and MDT review) and revisions.	X	X										
8. Fact sheet or story map – online publication			X	X								

BUDGET

This project is being supported by funding from the USGS ($57,600) and matched by $86,400 in MDT funding (table 5). The budget summary with breakdown by major cost category is shown in table 6.

Table 6. Budget summary by State and Federal Fiscal Year.

Federal Fiscal Year	USGS	MDT	Total
2019	$10,100	$15,160	$25,260
2020	$23,290	$34,930	$58,220
2021	$20,000	$30,000	$50,000
2022	$4,210	$6,310	$10,520
Total	$57,600	$86,400	$144,000
State Fiscal Year	**USGS**	**MDT**	**Total**
2019	$4,140	$6,220	$10,360
2020	$21,920	$32,880	$54,800
2021	$27,540	$41,300	$68,840
2022	$4,000	$6,000	$10,000
Total	$57,600	$86,400	$144,000

Table 7. Budget summary by major cost category by State and Federal Fiscal Year

Federal Fiscal Year	Salaries	Benefits and Overhead	Travel and vehicles	Equipment	Report Publishing	Total
2019	$10,610	$9,030	$560	$5,060	$0	$25,260
2020	$34,280	$20,800	$3,140	$0	$0	$58,220
2021	$32,660	$19,050	$680	$0	$4,130	$56,520
2022	$2,000	$1,000	$0	$0	$1,000	$4,000
Total	$77,550	$49,880	$4,380	$5,060	$5,130	$144,000

State Fiscal Year	Salaries	Benefits and Overhead	Travel and vehicles	Equipment	Report Publishing	Total
2019	$3,020	$1,880	$315	$5,060	$0	$10,280
2020	$31,830	$20,476	$1,667	$0	$0	$53,970
2021	$36,630	$24,032	$2,091	$0	$4,130	$66,880
2022	$6,059	$3,492	$307	$0	$0	$9,860
Total	$77,539	$49,880	$4,380	$5,060	$4,130	$140,990

STAFFING

Katherine Chase and Charlie Besteder will serve as co-principal investigators. Chase will manage the project, investigate avenues for data publication, and co-author the publication (fact sheet, data release, or story map). Besteder will lead the installation, operation and processing efforts, and will train Dan Armstrong, Civil Engineering MS Student at MSU, in all aspects of the LSPIV work. We will coordinate with Steve Holnbeck (Hydrologist) and the ongoing bridge scour investigations. We will investigate procedures/possibilities for data publication and transmission with Kirk Miller, Data Chief, and Seth Davidson, Hydrologist.

Table 8. Summary of hours, by Federal Fiscal Year.

	FISCAL YEAR	FISCAL YEAR	FISCAL YEAR	FISCAL YEAR	FISCAL YEAR	TOTAL ALL YEARS
	2019	2020	2021	2022	2023	
STAFF REQUESTS **Hours (Total Dollars includes actual, leave assessment & contingency factor)**						
Chase, Katherine J	51.82	136.04	200	46.16	0.00	434.03
Besteder, Charlie	71.26	136.04	1000	16.6	0.00	323.90
Vanvleet, Kyle D	19.43	90.69	0.00	0.00	0.00	110.13
GS 05/05	85.51	278.55	100	3.65	0.00	467.71
Miller, Kirk A	0.00	25.91	3.00	3.48	0.00	32.39

Davidson, Seth	0.00	45.35	40	5.35	0.00	90.69
Holnbeck, Stephen R	12.96	38.87	30	8.87	0.00	90.69

FACILITIES

Initially, the facilities, equipment, and workspace necessary for completing the project tasks will be provided by the USGS. We will explore using MDT web infrastructure for transmitting data.

POTENTIAL LIMITATIONS

Use of LSPIV for measuring streamflow and velocities is relatively new. Results from the proposed work might be limited by the status of the technology, and by how well field and equipment problems as well as software, processing and transmission issues can be resolved.

REFERENCES

U.S. Geological Survey, 2019, Guidelines for the collection of video for Large Scale Particle Velocimetry (LSPIV): U.S. Geological Survey Webpage, accessed March 11, 2019, at *https://my.usgs.gov/confluence/pages/viewpage.action?pageId=546865360*.