Author response to the reviews of the paper
"Nonparametric-based estimation method for river cross-sections with point cloud data from UAV photography URiver-X version 1.0 -methodology development
"

(Manuscript # gmd-2021-309)

Overall:

The goal is worthy, but the methodology, reproducibility, validation, and results are questionable. I recommend rejecting the paper.

The authors appreciate this reviewer's comment. The authors tried their best to improve the quality of the manuscript following this reviewer's comment.

1) *To generalize the proposed method, two typical shapes as V-shape and U-shape for a river channel were added from the other reviewer's comment and all three models as LOWESS, KLR, PolyFit models were applied to those models.*

2) *Two additional sites were added in the study area from this reviewer's comment and all four sites were applied to three tested models of LOWESS, KLR, PolyFit including the performance measurement of RMSE and MAE.*
3) *The authors agree that the general UAV sensor cannot penetrate the water surface and its application is limited. However, there are a number of streams that has no flow or close to zero during a dry season so that their cross-sections can be surveyed with a UAV photogrammetry. Even though no bathymetry data were tested in the current study, the authors consider that there are no reasons that this method cannot be applicable to the bathymetry data. The authors believe that this methodological development presented in the current manuscript might be beneficial and can be further generalized when the current proposed model has applied in the field.*
4) *The authors invite one professional in the hydraulic field as an author, Prof. Vijay P. Singh, to further revise and edit the manuscript. Prof. Singh made a significant contribution to revise and edit the manuscript. Hope this inclusion of an author is acceptable.*

- No discussion of UAV type used (sensor, height flown, date flown, resolution), which is essential to place this work within the vase literature devoted to UAV-based survey.

  Reply: The authors appreciate this reviewer's detailed comment and totally agreed with this comment. Before, the authors had considered that this information might not be necessary for this application because the proposed model can be easily applied and not restricted to those elements. According to this reviewer's comment, the discussion on the UAV type was added in the manuscript. Hope this modification is satisfactory to this reviewer.

"Aerial photos over the selected Migok-cheon were obtained with the unmanned aerial vehicle (also termed drone), DJI Phantom 4. This UAV is one of the most popular professional drones on the market and contains an advanced stereo vision positioning system that provides precise hovering even without satellite positioning support (Hamdi et al., 2019). The camera applied is FC3411 with ISO-110 and the image sensor of 1/2.3" CMOS, and the images taken from DJI Phantom 4 are 5472x3648 pixels at approximately 10 M with the horizontal and vertical resolutions of 75 DPI. Pix4Dcapture was employed to map the target area. The flight with a height of 75 meters was made on July 08, 2021."

- UAV cannot penetrate water depth, unless using bathymmetric technology (which was not discussed here). Therefore, the significant matching of the point cloud data with the engineered surveying data in the Figures is questionable.

  Reply: The authors appreciate this reviewer's insightful comment. The authors agree with this comment. UAV cannot penetrate water depth without additional technique. The authors are thankful for guiding what the authors missed before getting into detail. Accordingly, the authors point out the limitation of the proposed method and discuss how the water portion should be interpreted. For the engineered surveying data, the author considers that the tested stream is a dry stream and water depth is close to zero except the wet season (June-October). Hope this explanation acceptable to this reviewer.

- Why is the focus of this paper on channel cross-sections when no hydrological conditions are described, modeled, or assessed in terms of stream flow? In essence, the approach mentioned here can be used for any form of landscape survey analysis, and in fact, since the lack of UAV's ability to penetrate water surface is a limitation that was not adequately addressed in this study, the overall paper study should probably focus on general landscape patterns or dry streams for comparison.

  Reply: The authors are thankful to this reviewer's comment. The authors have worked at the hydrological field and modeled streams in South Korea. Most of streams in South Korea are dry except the wet season (June-October) since their watersheds are small and during the dry seasons, streams are without much flow. Also, UAV surveying has been studied in South Korea to surrogate ground surveying and provide additional information. Therefore, the authors consider that this application of UAV photogrammetry of river cross-sections can be beneficial to engineers and researchers even though there are limitations on UAV ability to penetrate water surface. Also, generalization of the proposed method might request extensive studies with a number of different types of surfaces and therefore, the authors include two more synthetic simulation data as U-shape and V-shape as well as two more sites for the case study. In addition, the LOWESS and PolyFit models were applied to all the case studies. Hope this discussion and additional work can be acceptable to this reviewer.

Specific Comments:

Lines 62-63 - This is based on UAV of wet versus dry pixels and not stream cross-section. Flood inundation from UAV is a well-established field. Stream cross-sections are not commonly used with UAV, as the sensors cannot penetrate the water depth and gather data of the full wetted perimeter. Traditional surveying is essential to supplement UAV or LiDAR-based point clouds for purposes of hydraulic modeling.

Reply: The authors appreciate this reviewer's pinpointing comment and agree with this comment in that traditional surveying is essential to supplement UAV point clouds. Following this reviewer's comment, the sentence was removed. In addition, the authors consider that UAV surveying have a considerable potential to apply it to river cross-sections since not only penetrating water surface technique is developing but there are a number of sites that are normally dry in dry season especially in South Korea with smaller watersheds. This has been discussed in the discussion section of the current manuscript accordingly as well as the conclusion.

"The results of the synthetic simulation study and the case study present that the proposed KLR model can demarcate the cross-sections of a river with different shapes. However, there are some limitations and conditions to apply the proposed model in the demarcation of river cross-sections. At first, UAV sensors cannot penetrate water depth unless bathymetric technology is not applied. Currently, river photogrammetry with bathymetry data has been applied to penetrate water body using specialized sensors, such as Light Detection and Ranging (LiDAR), which is called bathymetry LiDAR (Allouis et al., 2010; Fernandez-Diaz et al., 2014). The case study of the current study does not use the bathymetry data, since the water depth is very shallow and not critical to illustrate a river cross-section. The proposed KLR model with the point cloud data must be carefu lly applied to a dry stream or very shallow river with the water surface whose level is ignorable e specially for its discharge amount. Otherwise, a bathymetry data must be applied using a special sensor (e.g. bathymetry LiDAR). "

Lines 81-85 - A DEM, similarly, cannot penetrate water depth. In most DEM approaches, the depth of the stream still must be "burned" into the digital model, which requires knowing the depth a priori.

Reply: The authors appreciate this reviewer's insightful comment. We discussed the limitation of the proposed technique especially not penetrating water depth as mentioned in the discussion section. Hope this modification is satisfactory to this reviewer.

Lines 87-88 - Where do you demonstrate the strengths of higher-resolution points, compared to DEM resolutions from satellites, for purposes of hydraulic modeling? Generally, a very rough depiction of channel top width, bottom width, side slope, and Manning's n roughness is adequate for catchment-scale modeling in software such as HEC-RAS, since the water conservation equations are not highly sensitive to small changes in channel geometry.

Reply: The authors appreciate this reviewer's critical comment and totally agree with this comment that a rough depiction of river cross-section might be adequate for catchment-scale modeling. The authors do not compare the cloud point-driven data to DEM from satellite. However, the authors consider that the ground surveying also has its own limitation such as the ground surveying points are limited only to accessible locations by foot and time and cost *consuming procedure. Therefore, the authors consider that UAV surveying can also be a potential surrogate for its relatively cheap and time-saving. Furthermore, the river cross-section with UAV surveying can also be beneficial when the ground surveying has not been made and further resources cannot be available for additional ground surveying. In this case, the river cross-section with UAV surveying can extract any places inside the surveyed area. Also, detailed description of river cross-section might be helpful in other applications since related UAV techniques have been developed fast. This has been discussed in the discussion section. Hope this modification is satisfactory to this reviewer.*

Lines 90-93 - Natural river cross-sections do not typically form a trapezoidal shape, but rather a U-shape, due to erosion and sediment redeposition throughout the channel. Manmade channels are typically trapezoidal. It is unclear throughout the study if the sample stream is manmade or natural. I believe it is manmade, due to having engineered plans and appearing trapezoidal and straightened in the aerial figures, but little background information on this stream is able to be found online. Moreover, having UAV produce reliable riverine cross-sections in ungauged and natural areas is most useful for modeling hydrology in remote systems, as engineered systems have plans and field surveys available. This paper claims to address this gap but then, it appears, uses a man-made channel for validation.

Reply: The authors are thankful to this reviewer's comment for pointing out the authors' mistake. The applied river section is natural river cross-sections. Note that about 80% of national rivers and over 40% of local rivers over South Korea are manmade by revetment and the shape of manmade rivers are in trapezoidal. The application must be denoted to manmade river as mentioned by this reviewer's comment. The manuscript was modified accordingly as follows. Furthermore, A natural type of U-shape cross-section as well as V-shape was synthetically generated and applied in the simulation study. Hope this modification and additional work are satisfactory to this reviewer.

"Therefore, the current study proposes a demarcation technique for river cross-sections from the point clouds of UAV aerial surveying especially in a small study area. For example, about 80% of national rivers and over 40% of local rivers are maintained by the construction of dikes and revetments for flood control in South Korea. The shape of manmade rivers is mostly trapezoidal due to the stability and easy discharge. A cross-section of manmade rivers also often contains abrupt changes and small bumps as well as smooth variations from aging in natural rivers. The demarcation technique must reproduce the characteristics of manmade channels as well as the ones of typical rivers from aging in natural channels. The proposed demarcation model based on the KLR model was tested to determine whether to reproduce those characteristics."

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"3.3.1 U-shape cross-section

U-shape cross-section that are close to a natural river was tested. The U-shape cross was modelled with a power function from Neal et al. (2015) as

$$w_f = w_F \left(\frac{h_f}{h_F}\right)^{\frac{1}{s}} \qquad (13)$$

$$h_f = h_F \left(\frac{w_f}{w_F}\right)^{s} \qquad (14)$$

where w_f indicate the flow width while w_F is the bank-full flow width and h_f and h_F is the height of flow width and the height in a bank-full condition, respectively. Also, s is the parameter to vary *the shape of the cross-section. Here, s=5 was set as used in Neal et al. (2015) as the basic value. To design a similar bank in the trapezoid model in the previous test, h_F=5m and w_F=20m was used. The number of points for the U-shape cross-section is 262 points including the flat river bank and the designed cross-section was presented in a blue solid line with cross markers as shown in Figure 7. The synthetic point cloud data was simulated with Eq.(11) and the number of point clouds are 10 times of the U-shape cross-sections (i.e. 2620 points), shown with the red dots in Figure 7.*

This designed U-shape cross-section was fitted to the proposed KLR model and the other models as LOWESS and PolyFit and shown in Figure 7. Note that a=2 (see Eq.(10)) was applied for the KLR model from the result of the trapezoid case. The result in Figure 7 indicates that the KLR model matched well the U-shape cross-section without any deviation. Meanwhile, the LOWESS model fitted U-shape cross-section well in the middle part, but the connected part of the U-shape cross-section was not fitted well. The PolyFit model fairly fitted the U-shape cross-section with the 4^{th} model (i.e. PolyFit4) except slight deviation in the connected area between the slope and top. The PolyFit2 and PolyFit3 are poorly performed due to its limit of the flexibility."

3.3.2 *V-shape cross-section*

One of the unique shape of cross-sections is the V-shape for a river cross-section. The V-shape weir (or triangle shape, v-notch) was often built to provide a highly accurate solution for open channel flow measurement. Also, the V-shape river cross-section can be developed naturally when the sides are cut down and attacked by weathering. In addition, the loosened material slowly creeps down the slope by gravity. A V-shape cross-section was synthetically designed as shown in Figure 8 with the height of 4m and the top width of 16m so that the slopes of both sides are in 1:2. The cross-section was divided to 121points, including the flat river bank shown with the blue solid line with cross markers in Figure 8 and 10 times of the points was synthetically generated for point cloud data with Eq. (11) and presented with the red dots.

The point cloud data was fitted to KLR, LOWESS, and PolyFit models and shown in the panels (a), (b) and (c) of Figure 8, respectively. Here, a=2.0 was also employed for the KLR model. The result of the KLR model indicates that the V-shape cross-section also was fitted well by the KLR model with a minimal deviation at the acute angle bottom section. Meanwhile, the LOWESS model highly deviated at the acute bottom section and slight deviation was present at the top connected part. The PolyFit model did not fairly fit the V-shape model even with PolyFit4. Further higher order model was tested (i.e. PolyFit5 and PolyFit6) and no improvement was found with increasing the order for the PolyFit model.

Table 1 presents the estimated RMSE and MAE for three tested models of KLR, LOWESS, and PolyFit4 with trapezoidal, U-shape, and V-shape cross-section data. Note that only PolyFit4 was presented, since 4^{th}-degree was the best for the PolyFit models. The RMSE and MAE estimates present that the KLR model outperforms the other fitting models, while the other two models of PolyFit4 and LOWESS are comparable to each other for trapezoidal and U-shape cross-sections. For V-shape channel, the LOWESS much better performed than the PolyFit4, since the PolyFit4 is a parametric model that connects the points rather smoothly and abrupt change cannot be modelled well due to its limited flexibility. Overall, the simulation study indicates that the proposed KLR model is a good alternative to demarcate the different shape cross-sections.

Further, nonparametric models and other regression models, such as logistic regression (Ahmad et al., 1988; Elek and Márkus, 2004; Orlowsky et al., 2010; Simonoff, 1996), can be tested. However, the simulation study with the trapezoid channel that is similar to the real river cross-section shows that the presented KLR nonparametric model originally developed by Lee et al.

(2017) is suitable for demarcating the cross-section of a river. The major reason for the good performance is that the KLR model employs only k-nearest neighbor observations. This approach might not be beneficial, when an overall trend is needed and not enough observations are available. However, the point cloud data taken from UAV aerial surveying often provides a large enough number of points in the data set. Furthermore, the cross-sections in a manmade river can contain irregularity and abrupt changes by river aging. This feature can be captured only through fitting nearby observations. Therefore, the KLR model might be a suitable alternative to demarcating the cross-section of a river with the cloud point dataset."

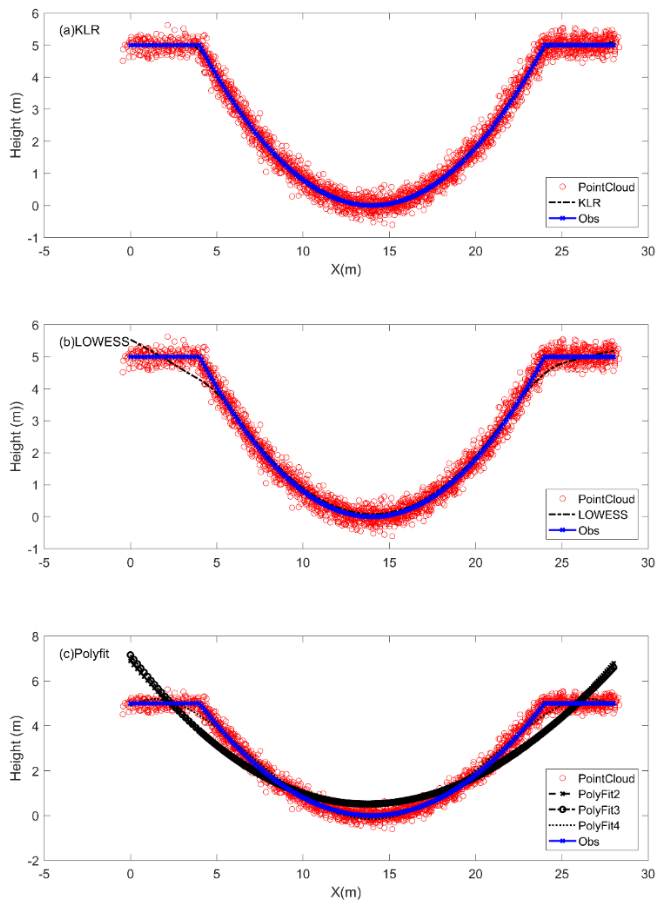

Figure 7. Synthetic U-shape river cross-section (blue solid line with cross markers) and the simulated point could data (red circles) of 10 times the synthetic channel (2620 points total) with Eq.(17) as well as the fitted estimates to KLR (the panel(a)), LOWESS (the panel(b)), and PolyFit (the panel(c)). Note that the U-shape river cross-section was designed with the power function as in Eqs. (19) and (20) and the U-shape was synthetically built following the reference of Neal et al. (2015) and the section was divided into 262 points.

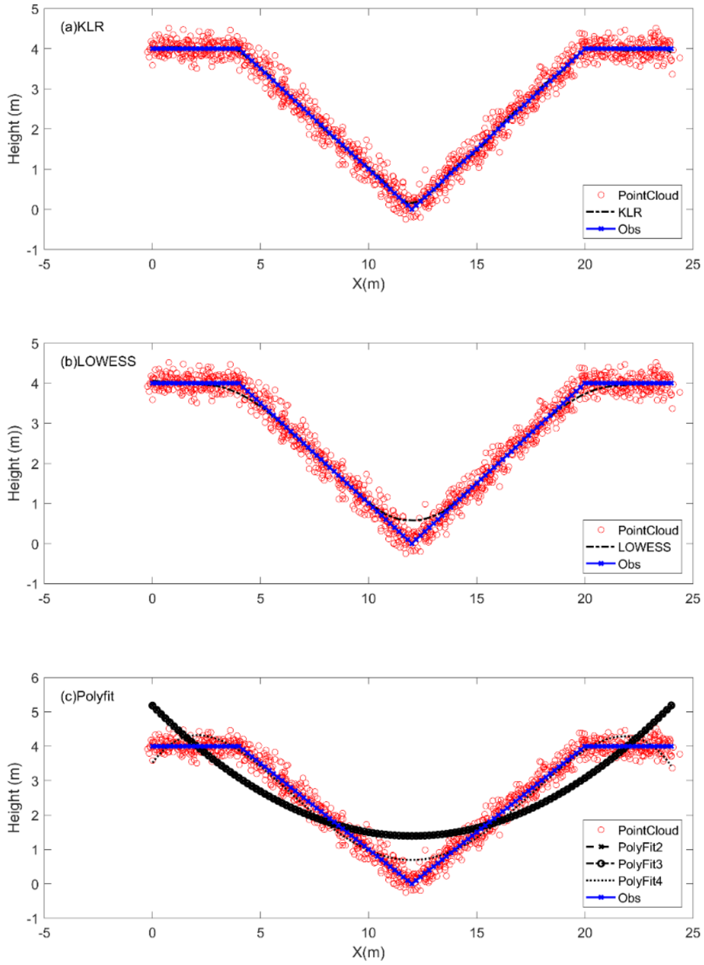

Figure 8. Synthetic V-shape river cross-section (blue solid line with cross markers) and the simulated point could data (red circles) of 10 times the synthetic channel (2620 points total) with Eq.(17) as well as the fitted estimates to KLR (the panel(a)), LOWESS (the panel(b)), and PolyFit (the panel(c)). Note that (1) the V-shape river cross-section was designed with the height of 4 m and top width of 16 m and the section was divided into 121points.

Section 2 - This section is very confusing. A more thorough discussion of how the different variables and equations relate to a stream and the UAV points would be helpful. There is no discussion of how the UAV was classified - how does the software know what is vegetation, water, concrete? What is the density? What kind of software is necessary for this? Section 2 could be transferred largely to an SI and explained in more hydrological and data gathering terms, here, for readability.

Reply: The authors appreciate this reviewer's detailed comment. The section was improved following this comment by indicating what each variable is indicated in the equations of Polynomial regression and KLR models using the units of each variable in SI as below. The code was developed with Matlab program. This was mentioned in the code availability section accordingly following this reviewer's comment. All the program and data were in the respiratory: Mendeley Data in <http://dx.doi.org/10.17632/xdw4cgnvhm.1>. The UAV does not classify the type of surface in the current study since the purpose of the model is to demarcate the river cross-section with the cloud point data. Hope this explanation acceptable to this reviewer.

"2.Mathematical Description

With the point cloud data obtained from UAV aerial surveying and postprocessing, the river cross-section must be demarcated. Polynomial regression can be simply applied to the point data. However, a fixed function of the polynomial regression with a few parameters is limited to the highly varied shape of the cross-section. Therefore, a nonparametric regression approach is adopted in the current study, especially K-nearest neighbor local regression (KLR). The KLR model was originally developed by Lee et al. (2017) to predict and simulate hydrologic variables describing a non-linear and hetroscedasticity relationship (non-constant variance of a predictand along with a predictor). The model also presents a strong interpolation ability, especially with a large number of datasets. Therefore, the KLR model was applied to the demarcation of a river cross-section, since the UAV aerial surveying and photogrammetry produce a large number of cloud points and the elevation of a river cross-section is highly non-linear. The KLR model was compared to a parametric model (polynomial regression) and another nonparametric model (LOcally WEighted Scatterplot Smoothing, LOWESS). A detailed description of polynomial regression and the proposed nonparametric regression model (KLR) is shown as well as the comparable nonparametric model, LOWESS.

2.1 Polynomial Regression

A polynomial regression model can be used when the relationship between a predictor (x) and an explanatory variable (y) is nonlinear or curvilinear. The M^{th}-order polynomial regression can be expressed as

$$y = \beta_0 + \beta_1 x + \beta_2 x^2 + \cdots + \beta_k x^M + \epsilon = \sum_{i=0}^{M} \beta_i x^i + \epsilon = \boldsymbol{x\beta} + \epsilon \qquad (1)$$

where ϵ is considered to be a random noise with zero mean and M is the degree of the polynomial regression model, called PolyFit. Here, x can be the distance from the base location in a river cross-section with a length unit (meter, in the current study) and y is the elevation with the same length unit (meter as well). "

2.2 KNN-based Local Linear Regression (KLR)

It is assumed that the current condition of the predictor x_t and its corresponding predictand y_t with the observed data (or cloud point data) pairs (x_i, y_i), for i = 1,…,n, is given for the n number of *data points (i.e., the selected cloud points). In the current study, the pair (x_i,y_i) refers to the observed data of x-coordinate (i.e. distance from the base location) and its corresponding elevation of y-coordinate for the i^th^ observed data (or cloud point data). Note that the base location refers to the point that the x-coordinate of a cross-section begins. The number of neighbors (k) is also assumed to be known. The predictand Y_t is estimated (i.e. the predicted elevation with the length unit, meter in the current study) with the target x_t distance according to the following steps:"*

Lines 151-153 - These assumptions defeat the entire point of using raw UAV data and comparing its applicability to derive cross-sections. In a natural channel, one would not know this geometry before-hand. Moreover, over a large watershed, it would change many times over, and must be extractable from the UAV data alone to be useful.

Reply: The authors appreciate this reviewer's insightful comment and totally agree with this comment. As mentioned in the previous comment, the word was changed into manmade river and the manuscript was modified following this comment. Hope this modification satisfactory to this reviewer.

"A manmade river cross-section is generally trapezoidal due to maximum discharge and easy construction (Chow, 1959)."

Lines 254 - Here is further discussion of a natural channel, but the model stream appears to be engineered.

Reply: Following this reviewer's current and previous comments, the sentence was modified as follows. Hope this modification satisfactory to this reviewer.

"However, the point cloud data taken from UAV aerial surveying often provide a large enough number of points in the data set. Furthermore, the cross-sections in a manmade river can contain irregularity and abrupt changes by river aging. This feature can be captured only through fitting nearby observations. Therefore, the KLR model might be a suitable alternative to demarcating the cross-section of a river with the cloud point dataset."

Section 4.2 - Why is a random line being used to re-project the data instead of the coordinate system used in the 2004 engineering study?

Note: The 2004 engineering study referenced is not able to be found online. For reproducibility, please host this study or the datasets using an URL, and preferably, a DOI.

Reply: The authors consider that the coordinate system from the engineering study was not provided in detail but the distance from the base and its corresponding elevation are. Besides, following the reviewer's another comment, the authors checked again whether more recent version of the engineering work is available. The authors found that there was a recent engineering study in 2019 and the reference was updated as well as the relative data. The URL link of the document was provided in the reference. Just by clicking download bar, one can download the manuscript. Hope this can be acceptable to this reviewer.

"BRTMA: Reports of Fundamental River Plan for Hwanggang Downstream Rivers (http://www.river.go.kr/WebForm/sub_04/sub_04_01_01.aspx?wNM=01&subTree=2&subPerio

d=999&subGrade=9&searRNM=%eb%af%b8%ea%b3%a1%ec%b2%9c&selSort=99). Agency, T. B. R. T. M. (Ed.), Ministry of Land, Infrastructure and Transport, Busan, 2019."

Section 4.3.1 - Interesting rationale for why you chose these two sites, but where, then, is this compared (a site with many overlapping panels versus one on the edge of the survey area)? Pros/cons? Limitations? Where do you compare to traditional DEM or LiDAR? Moreover, I think having only two sites for comparison when you had thousands of data points is not ideal. It is not immediately clear how long this stream is, but in the event that it is substantially long, more than two cross-sections will be required.

Reply: The authors appreciate this reviewer's comment and agree with his comment. Following this reviewer's comment, the authors added two more sites and added the result in the manuscript. Note that although the stream was long and contain more sites surveyed, the UAV photographed area contains limited sites. The original engineered surveying for the tested sites was included in the supplementary. Note that the engineered surveying was done by private company. Therefore, the public report can be accessible to the public. However, its detailed data including the engineered surveying data is not available to the public. The surveying data of only the four sites were provided in the supplementary by extracting from the report. The authors believed that the reproduction of the current study has no problem since the employed four sites were provided in the supplementary. Hope this improvement and circumstances satisfactory to this reviewer.

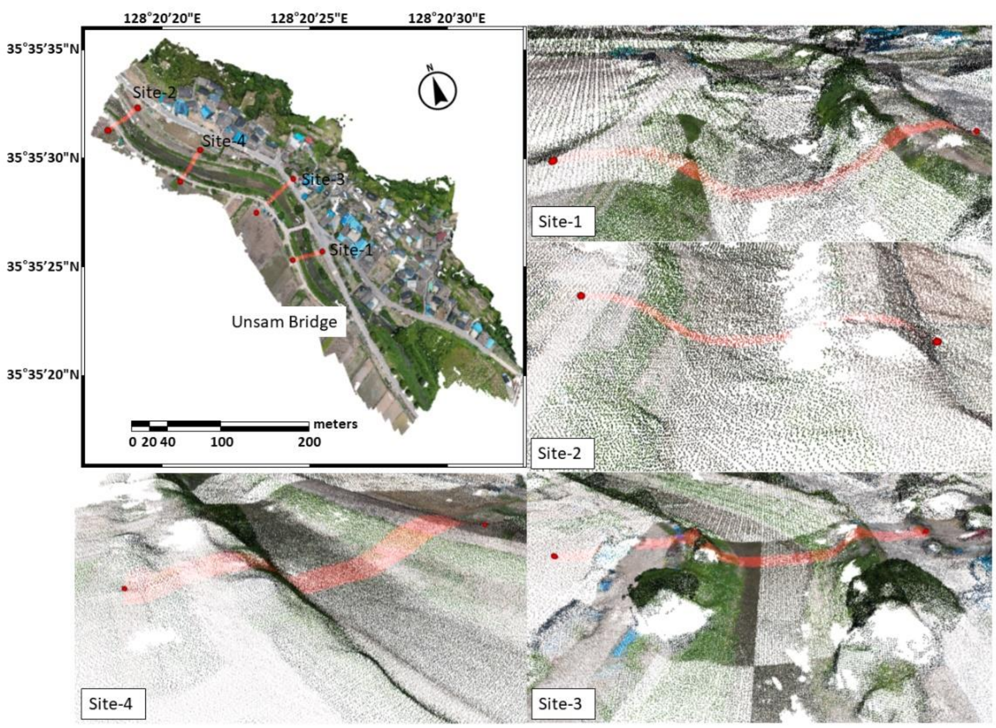

Figure 10. Locations of four tested sites in the Migok-cheon stream. Note that the other four panels surrounding the left-top panel magnify each tested site by showing the point clouds of the observed data taken from the UAV photographs. The aerial images were taken from the authors.

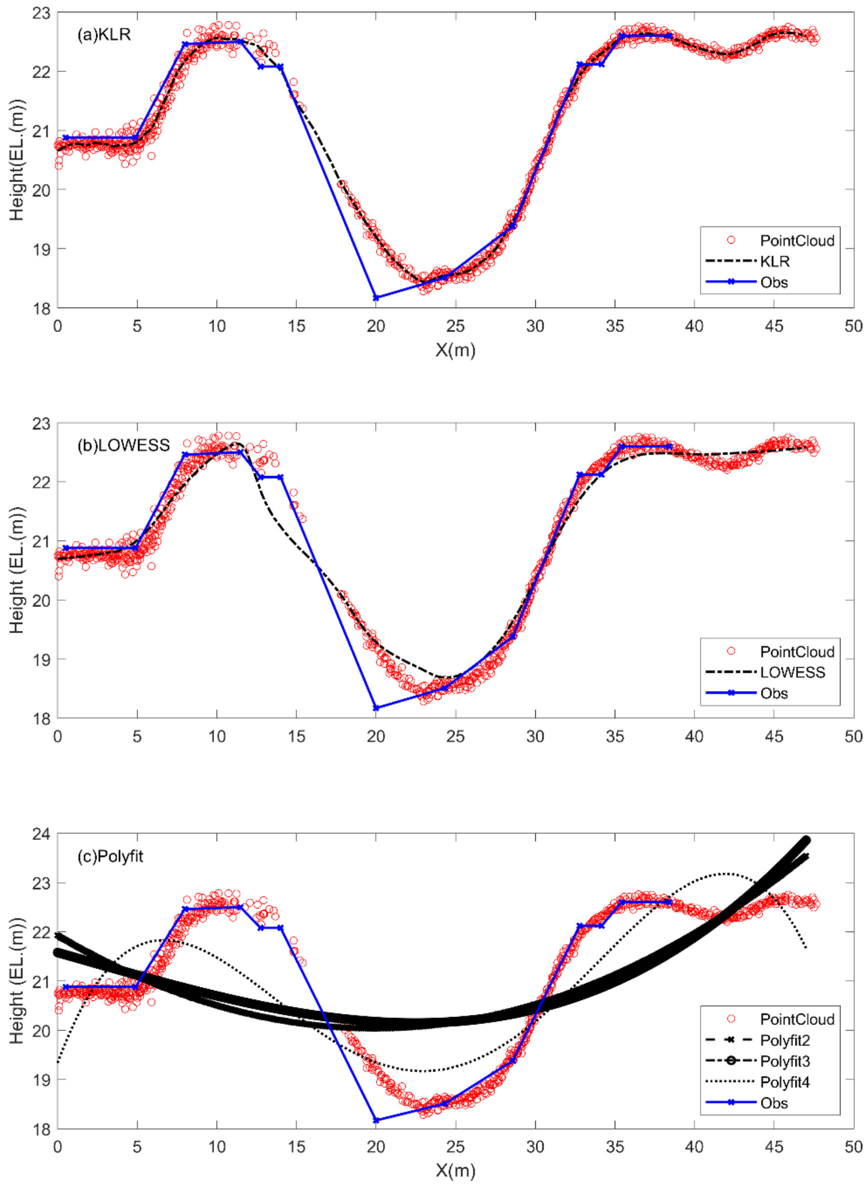

Figure 13. Point cloud data (red circles) for Site-2 and model-fitted line (black dashed line) with KLR (panel(a)), LOWESS (panel(b)), and PolyFit (panel(c)) as well as the observed surveying. Note that (1) the observed line was drawn from the previous surveying in BRTMA (2019); and (2) the detailed information including the map is attached in Supplementary Material.

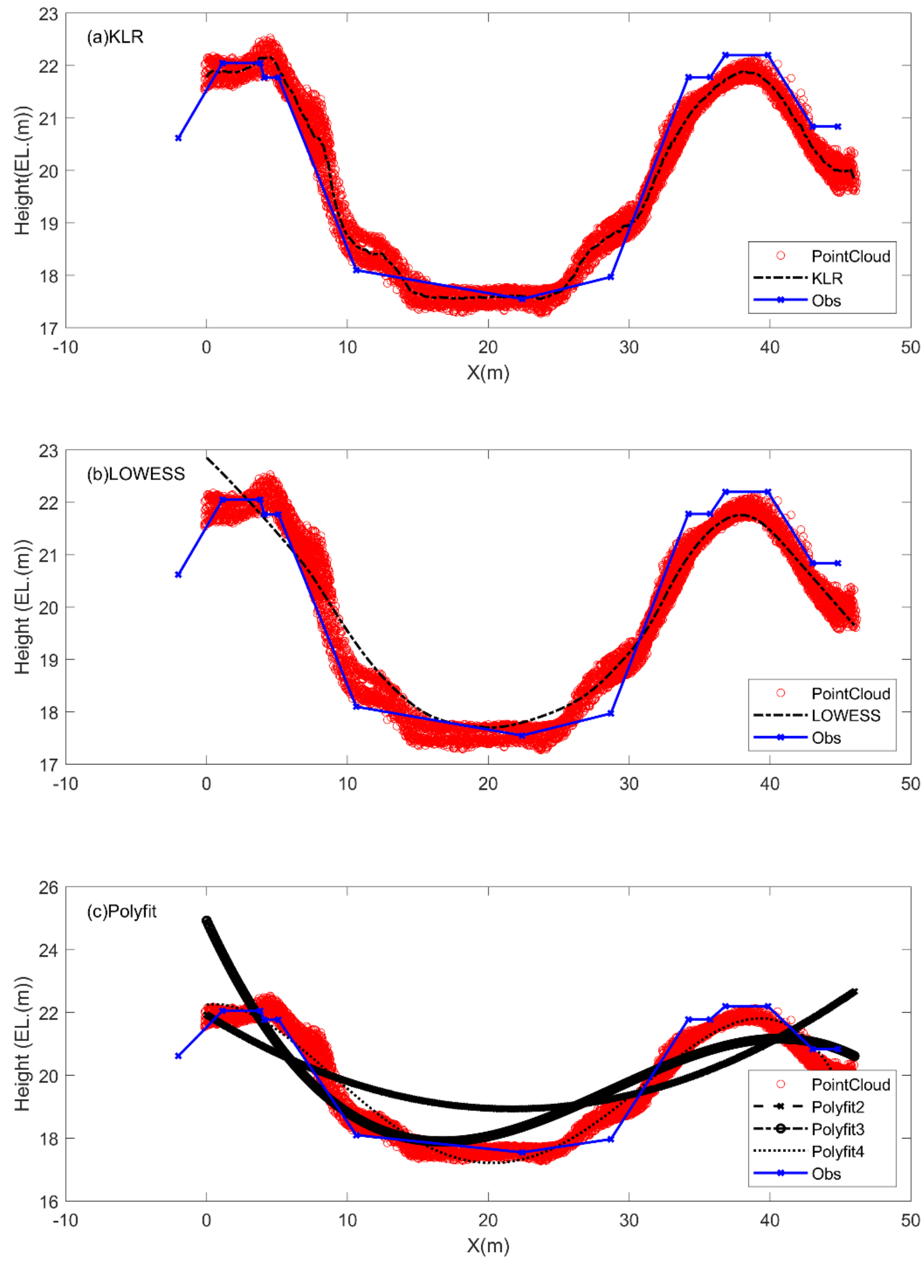

Figure 14. Point cloud data (red circles) for Site-3 and model-fitted line (black dashed line) with KLR (panel(a)), LOWESS (panel(b)), and PolyFit (panel(c)) as well as the observed surveying. Note that (1) the observed line was drawn from the previous surveying in BRTMA (2019); and (2) the detailed information including the map is attached in Supplementary Material.

Section 342 - "natural bumps" at the bottom are probably sediment deposition. It is uncertain why this approach was compared to 2004 field data (is the 2004 study "as-builts" or engineered plans? Which can vary significantly. Or actual raw survey data?). This is of the utmost importance to understand in order to verify if the results are believable.

Reply: Following the reviewer's another comment, the authors checked thoroughly again whether more recent version of the engineering work is available or not. The authors found that there was a recent engineering study in 2019 and the reference was updated as well as the relative data. The URL link of the document was provided in the reference. Just by clicking download bar, one can download the manuscript. Hope this can be acceptable to this reviewer.

"BRTMA: Reports of Fundamental River Plan for Hwanggang Downstream Rivers (http://www.river.go.kr/WebForm/sub_04/sub_04_01_01.aspx?wNM=01&subTree=2&subPeriod=999&subGrade=9&searRNM=%eb%af%b8%ea%b3%a1%ec%b2%9c&selSort=99). Agency, T. B. R. T. M. (Ed.), Ministry of Land, Infrastructure and Transport, Busan, 2019."

Line 348 - Why is there a gap in a large swatch of Site-2's cross-section? Was there a shadow here in flying the UAV? What does this mean for the reliability of such an approach? Could you have gathered a cross-section slightly upstream and downstream of this location for more robust survey results? Was this an issue with post-processing?

Reply: The authors consider that the gap in Site 2 should be shadow in flying the UAV. In a point view of UAV surveying this might be a drawback while in a point view of the proposed technique, this can be beneficial since those gaps can be interpolated with the proposed KLR technique. The surveyed data is available for four sites and added according to the previous comment. From the experience of this reviewer, this type of gaps is observed from time to time in a river surveying. This drawback and benefit from KLR have been fully discussed in the discussion section of the manuscript. Hope this explanation acceptable to this reviewer.

Section 4.3.3 - I do not believe you can accurately estimate wetted perimeter without surveying below the water surface. Moreover, what is the point of calculating this? There was no hydraulic modeling done to compare how the UAV-derived A(H) and P(H) compared to stream flow analysis from traditionally-derived surveying and/or satellite data. It is also unclear how you gathered this data when only comparing for two "sites" or cross-sections along the length of the stream.

Reply: The authors appreciate this reviewer's insightful comment. Following this reviewer's comment, the authors decided that the section must be removed. Hope this modification understandable to this reviewer.

Results Section: There is no discussion here of the LOWESS method results and how it compared to the proposed KLR model. How does your proposed approach benefit us in comparing to how UAV-based survey is typically interpolated? Comparing both the KLR &

LOWESS to field survey (that was gathered recently) would be the most interesting and useful results.

Reply: From this reviewer's comment, the authors compare the LOWESS to the KLR as well as Polynomial regression for the case study including two additional sites. Furthermore, the authors also added more simulation studies for V-shape and U-shape synthetic cross-sections. The comparison was also made for these synthetic cross-sections. Note that more recent report was gathered and applied to the current revised manuscript. Also, RMSE and MAE were estimated with the modeling estimates and the observed data to validate the proposed KLR model. The authors wish that the modification is satisfactory to this reviewer.

Line 396-397 - From the aerial image, it does not appear this channel has much vegetation (mowed). This is an unnecessary discussion.

Reply: The authors checked that the channel was not mowed but natural.

Line 398 - I think the proposed method here is actually more useful for buildings or natural landscapes and not for streams, given the questionability of how the camera obtained survey points below the water surface. Therefore, it is unclear why the paper focuses on channel cross-sections and not UAV-smoothing in general. There were no hydrologic models performed, no climate discussed, no stream flow gauges, etc.

Reply: The authors appreciate this reviewer's comment suggesting the extension of the study. The authors have applied the proposed algorithm in hydrologic modeling such as HEC-RAS, produced separate application studies. For example, the current model was applied in finding the most vulnerable site to a flood for a flood early warning system (FEWS). The most vulnerable section was defined from the UAV-data and its section was drawn with the KLR algorithm. The flow amount and the corresponding water-level was estimated with HEC-RAS. The study was submitted to a journal and in review as a case study. In the current study, the focus was to provide the original model development. The manuscript could be too long to include the hydrologic application in the current study. Hope this explanation acceptable to this reviewer.

Line 400-402 - Why discuss LOWESS here (or anywhere in the paper) if it was not actually used? Although, the figures seem to suggest it was indeed used, but not robustly compared and discussed? There seems to be a discrepancy here.

Reply: The authors appreciate this reviewer's comment. The LOWESS and polyfit models were compared with the proposed KLR model as shown in Figure 5 presenting that the KLR model is comparable to the other models. From this reviewer's comment, the description of LOWESS model was added in the mathematical description section. The authors agreed that the full detailed comparison and further comparison should be made. Following this reviewer's comment, the detailed explanation about the LOWESS was made in Section 2.3 and full comparison was made with the four tested sites in the revised version of the current study. Hope this modification acceptable to this reviewer.

"2.3 LOcally WEighted Scatterplot Smoothing (LOWESS)

LOWESS was proposed by Cleveland (1979) as a nonparametric regression. The LOWESS with one explanatory variable (x_t, the distance from the base location for x-coordinate) and one predictor variable (y_t, the elevation of the corresponding t^{th} point) can be defined as

$$y_t = m(x_t) + \varepsilon_t \qquad (11)$$

where the regression curve $m(\boldsymbol{y}_t)$ is the conditional expectation $m(x_t) = E(Y|X = x_t)$. The LOWESS estimate can be defined as

$$\widehat{m}_{LOWESS}(x_t) = \vec{x}_t^T \widehat{\boldsymbol{\beta}}_t^{LOWESS} \qquad (12)$$

where

$$\widehat{\boldsymbol{\beta}}_t^{LOWESS} = (\overleftrightarrow{\boldsymbol{X}}_t^{\ T} \boldsymbol{W}_t \overleftrightarrow{\boldsymbol{X}}_t)^{-1} \overleftrightarrow{\boldsymbol{X}}_t^{\ T} \boldsymbol{W}_t \boldsymbol{y} \qquad (13)$$

with

$$\overleftrightarrow{\boldsymbol{X}}_t = \begin{pmatrix} 1 & x_t^1 - x_1^1 \\ 1 & x_t^1 - x_2^1 \\ 1 & \vdots \\ 1 & x_t^1 - x_n^1 \end{pmatrix} \qquad (14)$$

and

$$\boldsymbol{W}_t = \boldsymbol{H}^{-1} diag[K_d(\boldsymbol{H}^{-1}(\boldsymbol{x}_t - \boldsymbol{x}_1)), \cdots, K(\boldsymbol{H}^{-1}(\boldsymbol{x}_t - \boldsymbol{x}_n))] \qquad (15)$$

*with the bandwidth matrix, **H**. The major characteristic of LOWESS is to employ the following kernel function:*

$$K_d(z) = \begin{cases} (1 - |z|^3)^3 & |z| < 1 \\ 0 & otherwise \end{cases} \qquad (16)$$

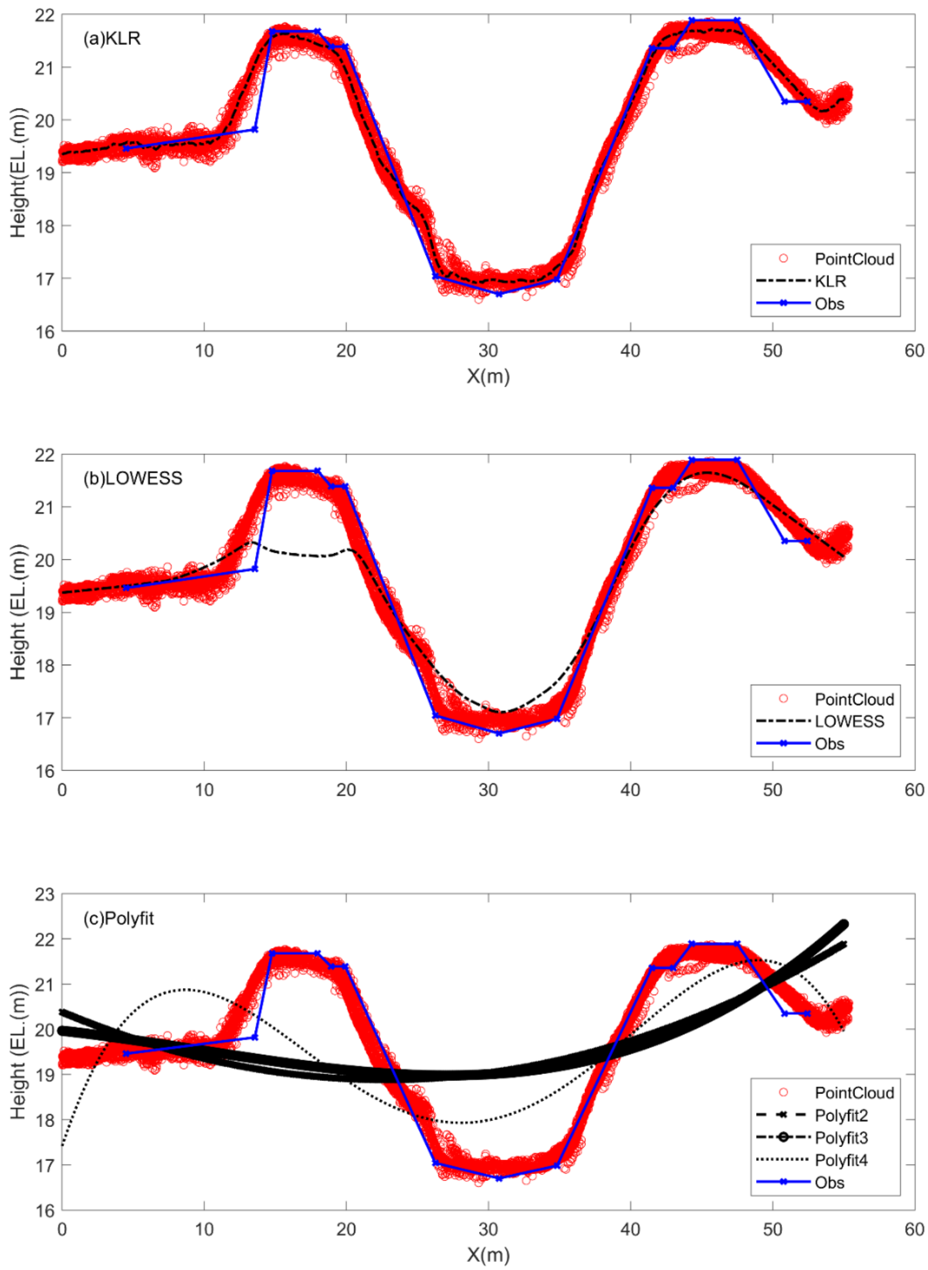

Figure 12. Point cloud data (red circles) for Site-1 and model-fitted line (black dashed line) with KLR (panel(a)), LOWESS (panel(b)), and PolyFit (panel(c)) as well as the observed surveying. Note that (1) the observed line was drawn from the previous surveying in BRTMA (2019); and (2) the detailed information including the map is attached in Supplementary Material.

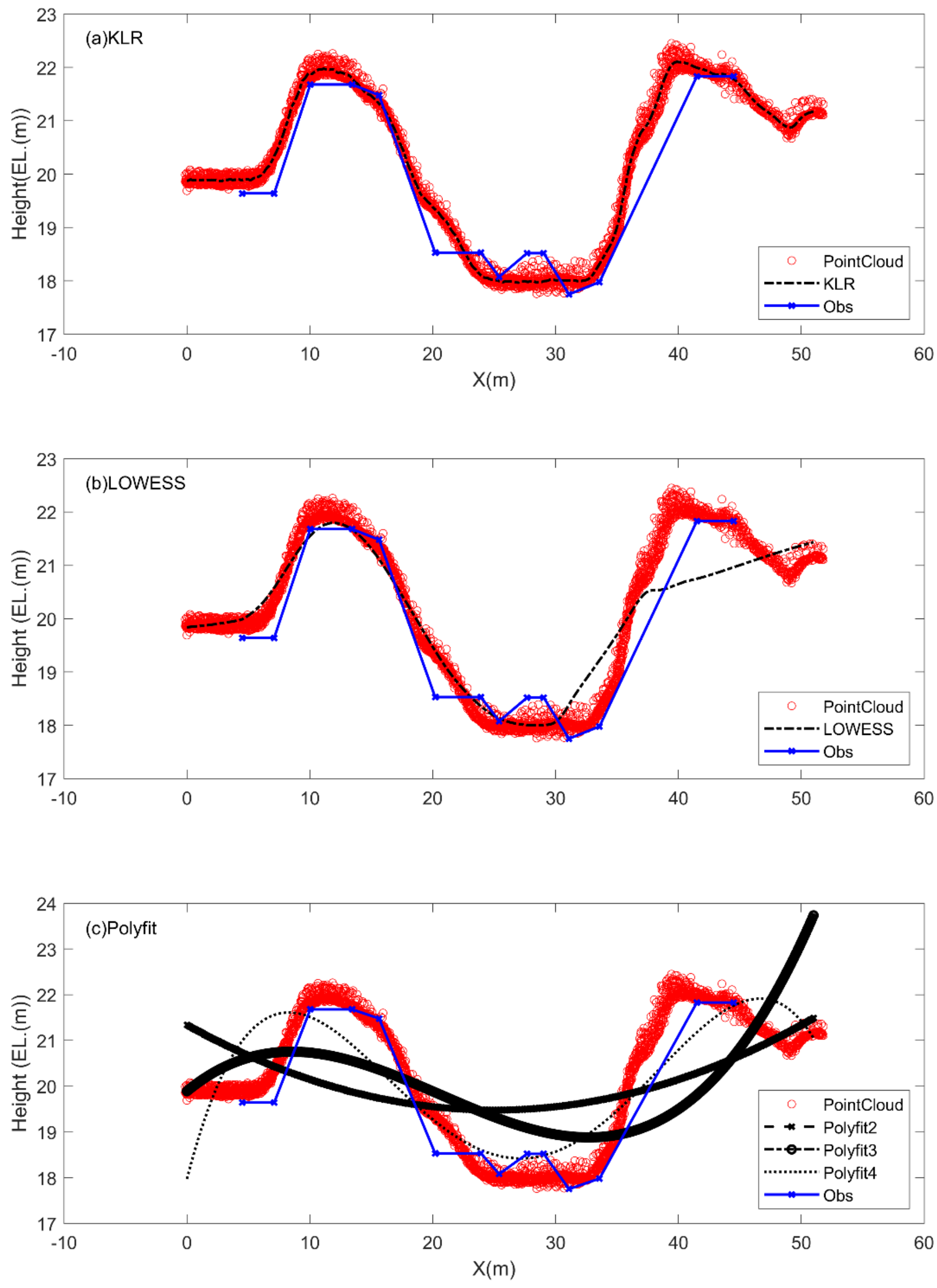

Figure 15. Point cloud data (red circles) for Site-4 and model-fitted line (black dashed line) with KLR (panel(a)), LOWESS (panel(b)), and PolyFit (panel(c)) as well as the observed surveying. Note that (1) the observed line was drawn from the previous surveying in BRTMA (2019); and (2) the detailed information including the map is attached in Supplementary Material.

Figure 1 - How did the UAV (red points) capture data below the sub-surface of the channel ground? Does the 4x6x6m geometry apply throughout the stream reach? If so, how is this actually surveyed data of a natural channel, rather than a very rough simplification of an engineering design? The elevation of the bottom channel being 18m is *the* most important discrepancy here. I do not believe this is the actual flowline elevation, and I cannot check the original plans referenced to verify. UAV cannot penetrate water, therefore, the red dots are likely the surface of the water, and the RMSE comparisons would all be different if the blue line dipped much lower than is shown in the Figure.

Reply: The authors appreciate this reviewer's insightful comment and agree that a UAV camera cannot capture below the sub-surface of the channel ground unless the sensor has a specific feature (e.g. bathymetry LiDAR) to penetrate the water. Therefore, the limitation was discussed in the discussion section such that the UAV aerial camera cannot capture data below the sub-surface of the channel ground unless the camera has a specific feature to penetrate the water. Therefore, the proposed KLR model with the point cloud data must be carefully applied to a dry stream or very shallow river with the water surface whose level is ignorable especially to its discharge amount.

This figure does not demonstrate the real channel but the synthetic channel and the point cloud data was simulated with Eq.(11). Note that this section is the simulation study meaning that the trapezoid shape data was intentionally designed (blue solid line) by the authors and simulated with Eq.(11) (red dots). The 18m of the bottom channel is also an assumed elevation not real. The authors updated the caption to avoid the confusion.
Hope this modification satisfactory to this reviewer.

"

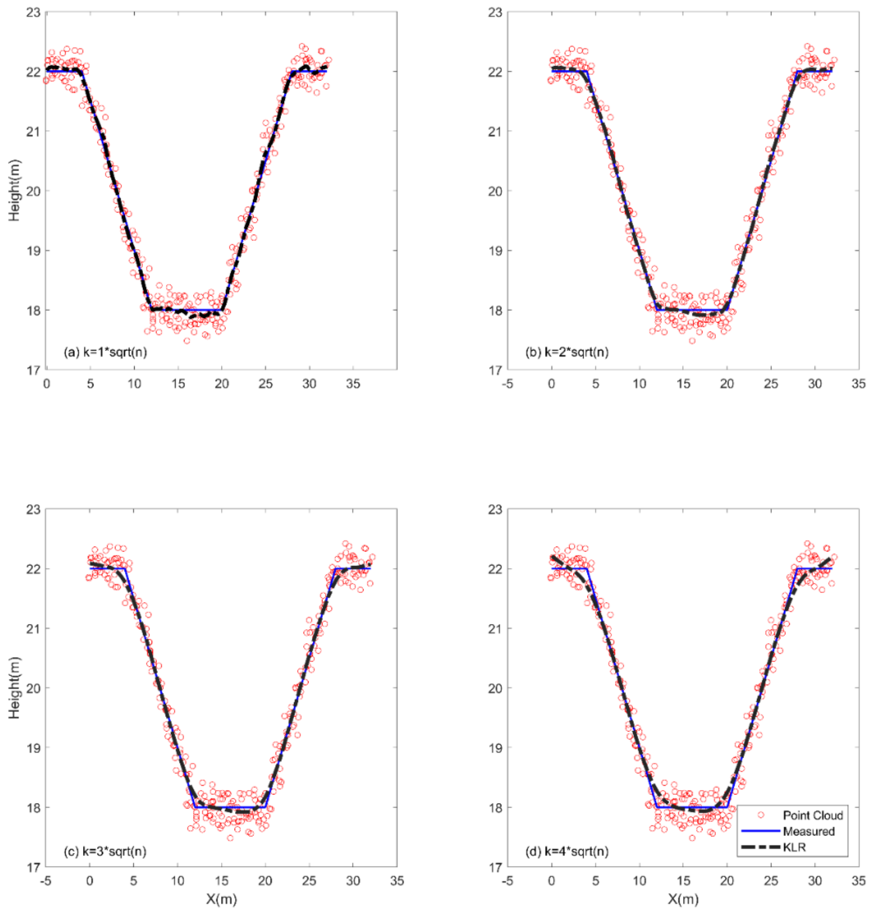

Figure 1. Assumed synthetic trapezoidal channel (not a real one) to test the KLR model (thick black dotted line) for the point cloud data with different portions of the number of neighbors ($k = a\sqrt{n}$, here a=1, 2, 3, and 4 at each panel). Note that (1) the trapezoidal sections are consistent with a 4 m top both sides and a 6 m base width as well as a 1:1 side slope with a 6 m height; (2) the number of points for the channel was divided at each 0.1 m to a total of 161 points (blue line); (3) 2 times the divided data are simulated with Eq.(17) to a total of 322 points (red dots); and (4) the elevation of the bottom channel was assumed to be 18 m."

Figure 2 - Why are there so many more red points here? Is this the other Site? It is not clear from the captions, which should be self-explanatory.

Reply: The red points were simulated from Eq.(11) with assuming them as the cloud points (not real data). Compared to Figure 1, the simulated data in Figure 2 is five time larger than the points (total 1610 points). This difference was intentionally made since the number of data collected from UAV images can be different in each case. The intention was to show how the proposed KLR model behaves when there is a small number of cloud points or a large number of cloud points. The caption was modified accordingly to avoid the confusion in the following. Hope this modification is satisfactory to this reviewer.

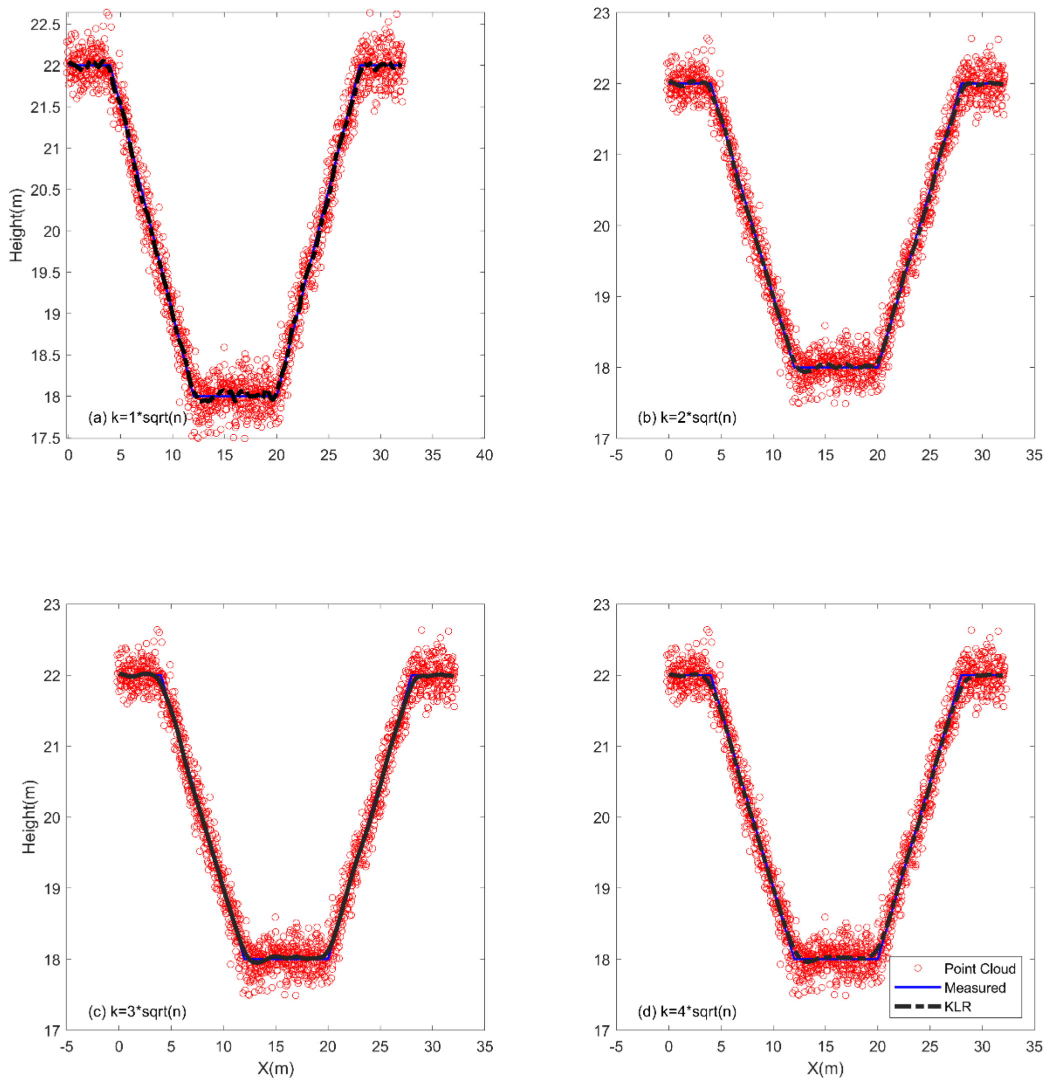

Figure 2. Assumed synthetic trapezoidal channel to test the KLR model for point cloud data with different multipliers of the number of neighbors ($k = a\sqrt{n}$). Note that (1) the trapezoidal sections are consistent with a 4 m top both sides and a 6 m base width as well as a 1:1 side slope with a 6 m height; (2) the number of points for the channel was divided at each 0.1 m to a total 161 points (blue line); (3) 10 times the divided data are simulated with Eq.(17), to a total of 1610 points (red dots) and it is 5 times more simulated cloud points than the ones in Figure 1. The difference between the number of points in the current and the one in Figure 1 was intentionally designed to illustrate how the proposed KLR model performs when there is a small number of cloud points or a large number of cloud points*; and (4) the elevation of the bottom channel was assumed to be 18 m.*

Figure 3 - RMSE here does not match RMSE in Figure 4. Optimal RMSE is 0.2-0.5, which is not achieved here, although from the looks of the figures, it should have been. How do you explain this variance between the figures and these plots of RMSE?

Reply: The authors appreciate this comment. The optimal RMSE is about 0.05 at the panel (a) of Figure 3 and 0.032 at the panel (b) of figure. This result of Figure 3 is not much different from Figure 4. Hope this explanation is acceptable to this reviewer.

Figure 5 - Ensure legend texts are full words, not "PolyFit2/PolyFit4", which are not described in the text. LOWESS is plotted here but not described in the text. How does your approach improve LOWESS? LOWESS appears to be quite close to the blue "measured" line.

Reply: *PolyFit2/PolyFit4 were described in the manuscript in Eq. (2) and (4). LOWESS is described already in appendix, but moved to the section2 according to this comment. The comparison between LOWESS and KLR to the case study was also made in the manuscript. Also, further comparison was made with V-shape and U-shape simulated data.*
Hope this modification was acceptable to this reviewer.

Figure 7 - What is Unsam Bridge? (Remove underscore). It is not described in the text. Showing some major cities would be helpful. I do not think zooming so far out in the top panel is essential. Rather, the lat/lon coordinates should be made more clear and placed on all geospatial map panels in the figures. Where does Hapcheon flow? It looks like where Migok-cheon enters Hapcheon, the stream suddenly ends? What is the lake I am looking at in the Hapcheon panel? What is the background of Migok-cheon? Was this stream engineered to, for example, capture additional flow back in 2004? From a brief look at the aerial in Figure 9, it does not appear to be fully-natural.

Reply: The authors appreciate this reviewer's detailed comment. There is no major city in this study area. Instead, Seoul and Busan were placed in the large scale panel. The lat/lon coordinates were made clearer on all geospatial map panes. The river named Hwanggang River flows through the area and the Migok-cheon stream was joined to Hwanggang River whose major discharge was made from the Hapcheon Dam. The background of Migok-cheon stream was discussed in the study area section. The specific year that the stream was engineered cannot be found in literature. Hope the improvement of the figure and the discussion of the study area are satisfactory to this reviewer.

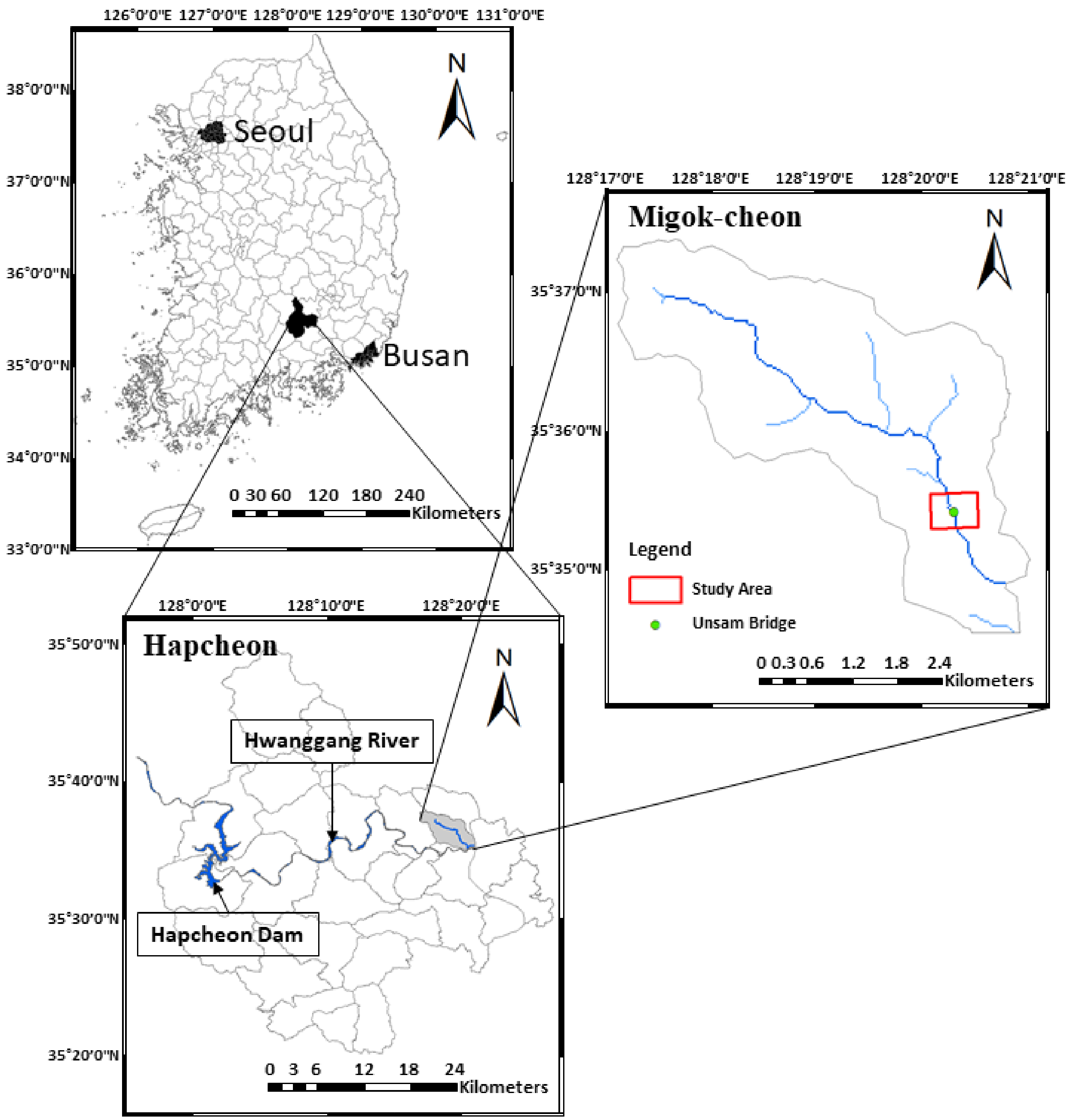

Figure 9. Study area of the applied stream, Migok-choen in South Korea, located in the province of Hapchoen-gun.

Figure 9 - What is (a), (b), and (c) in the caption? Coordinates, scale, and N-arrow are essential to locate in space. Improve legibility. The stream looks engineered to meander along the neighborhood/road and also is full of water. The UAV points along the bottom of the channel area are all white, which suggests to me they are capturing the water elevation.

Reply: The authors appreciate this reviewer's detailed comment. The caption (a), (b), (c) was removed since it is not necessary in explanation of the figure. Scale and N-arrow were added accordingly. The authors consider that the coordinates are not critical in this figure since its location is explained in advance. When we performed the UAV surveying, the stream was rarely flowed and its water depth was very shallow. The authors carefully checked the white area and noticed that the white area mostly come from shade. A white area without point cloud often occurs in the side of the riverbank. Hope this explanation acceptable to this reviewer.

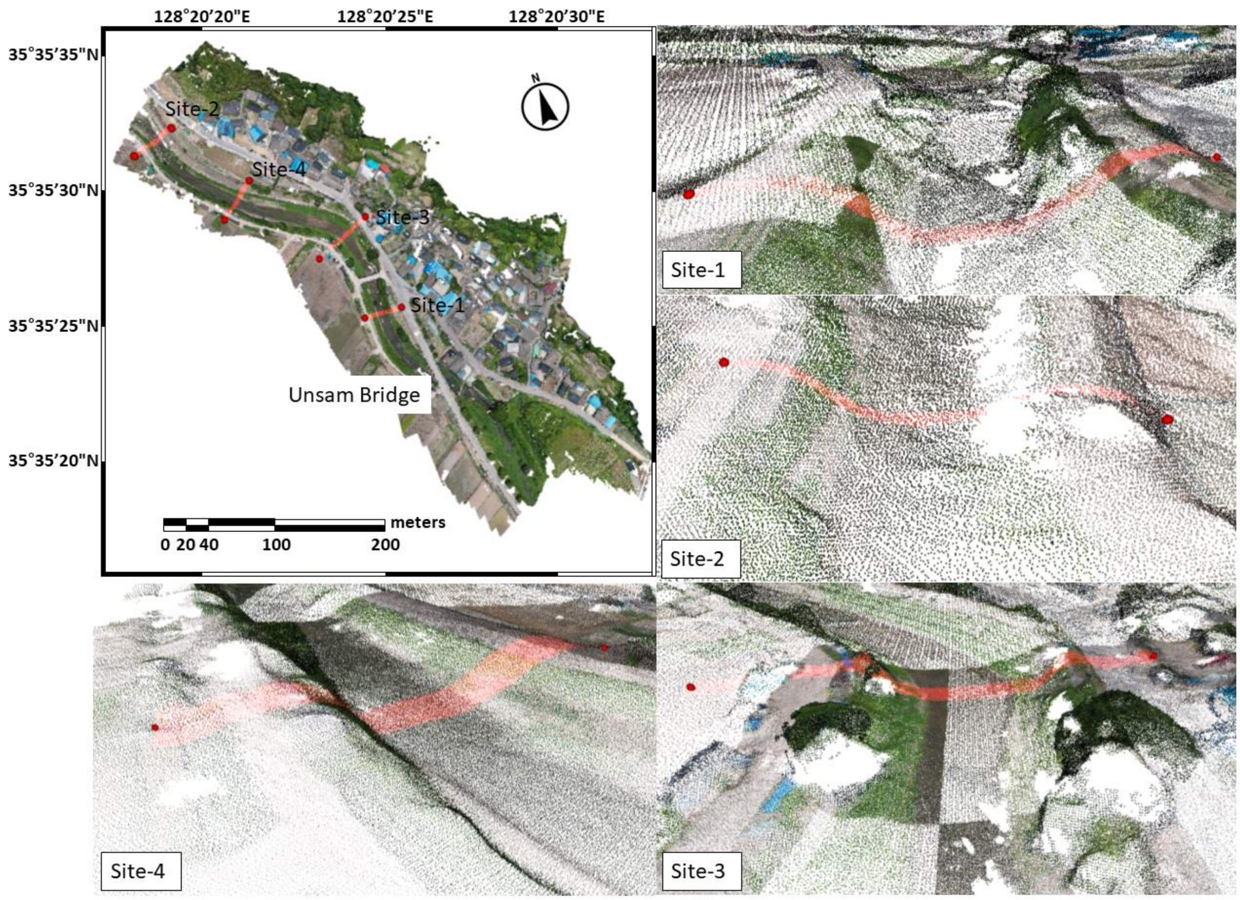

Figure 10. Locations of four tested sites in the Migok-cheon stream. Note that the other four panels surrounding the left-top panel magnify each tested site by showing the point clouds of the observed data taken from the UAV photographs. The aerial images were taken from the authors.

Figure 10 - Here you state the surveying was done in 2005, yet the engineering study was 2004. This is not typical. Please confirm how and when the data was obtained for validation and provide public access for reproducibility of results. This site appears natural, whereas Figures 2, 5, and 6 seem to showcase a trapezoidal/man-made channel. Did you study two separate streams? If so, where, how, why? I am confused about the case study matching the figures.

That is true that Figures 2, 5, and 6 seem to showcase a trapezoidal/man-made channel. Those figures are in the simulation section. Simulation study was made to illustrate how the proposed KLR model behaves in the idealized channel. From the other reviewer's comment, the authors also included V-shape and U-shape channels. Simulation studies are useful to illustrate the performance of the proposed model before a real application.

Sorry for the mistake. It is not 2005 but 2004. The engineering study was updated by finding the recent work (BRTMA 2019) for this area (see the reply from the comment above). All the data employed as the case study was included in the supplementary material. Also, the simulated station data was included in a excel file.

Hope this modification is acceptable to this reviewer.