# Seismic Approach to Quality Management of HMA

## MnDOT Contract No. 1034287

## Report – 4th Quarter, 2020


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# SUMMARY

We provide a progress report for the 4th quarter of 2020. This report summarizes key topics regarding work in progress. Details and supporting documents can be found on the project website. The overall progress has been summarized by month and has also been posted on the "Progress" page of the project site.

Progress summary of the previous quarter (Q3-2020) was presented in the report posted online. This report summarizes the progress made since then for 5 tasks specified in the Scope of Work (SOW), namely:

- Task #1: Project Management and Administration
- Task #2: Hardware Development (Seismic Data Acquisition System) & Testing
- Task #3: Software Development & Testing
- Task #4: Delivery and Demonstration of Seismic Data Acquisition System and Software
- Task #5: Final Report

Progress on the first 3 tasks (#1 – #3) are summarized in this report. First, we provide brief snapshots of monthly progress that has been posted online. Second, quantified indices are tabulated for all three tasks for both prime (Park Seismic LLC) and sub (Norrfee Tech, AB) contractors. Lastly, projections for the next quarter (Q1-2021) are prepared by compiling feedback and plans from all project participants.

# MONTHLY PROGRESS

## October, 2020

- **Project Management and Administration (Task #1)**

  The 3rd quarterly report (Q3-2020) was prepared and submitted by all (4) project participants. It was posted on the web page in the form of a report.

  The monthly meeting was organized via Skype and the minutes were posted on the web page by the administration staff. The monthly invoicing and payment to the sub-contractor has been managed by the staff. The project web site has been updated a few times each month to reflect the progress status.

- **Modules for Velocity (Vs) and Thickness (H) Evaluation - Algorithm Completed (Task #3)**

  The modules in ParkSEIS that can evaluate the shear-wave velocity (Vs) and thickness (H) of an HMA layer automatically have been completed in algorithmic development. They have been tested through both numerical modeling and actual field data sets in accuracy and reliability. The modules will be further tested and improved once the 1D acquisition system being developed is available for more extensive field measurements within the next few months (e.g., November - December). The algorithmic development is further explained in this report. Two methods (Methods I & II) are developed as temporary options for the calibration and evaluation purposes through further field tests. Results obtained from a set of field data (September 1, 2020) are displayed online. The data set includes seismic measurements at 100 consecutive points along the

road (approximately 100-m long section) by using a field approach presented here.

The values of velocities (Vs's) from the two methods (I & II) fall within a reasonable range of HMA layer (e.g., 1300 m/s ≤ Vs ≤ 1500 m/s). The overall variation trend is quite smooth, indicating measured values from both methods are realistic. Velocities (Vs's) from both methods are similar within approximately 1% difference. The Vs's from Method II are slightly higher than those from Method I (approximately by 1%). The S/N values from Method II, however, are significantly higher approximately by 5%. In consequence, Vs's from Method II are believed to be more accurate. On the other hand, thicknesses (H's) evaluated from the two methods are different by as much as 30% overall. In addition, the changing trends are fairly abrupt and irregular, indicating less realistic trends than those of the velocity (Vs). Thickness values are therefore much less reliable than the velocity values. The S/N values for H evaluation from the two methods are almost (99%) identical. The H trend from method II, however, seems to be more consistent than that from method I. In this sense, H results from method II are believed to be more reliable, which is consistent with the result from the modeling data. For more details and further information, please see this report.

- **TDMS Data Conversion Module Completed (Task #3)**

  The module in ParkSEIS software that converts a TDMS file into the ParkSEIS (PS) format has been finalized into three (3) types. No further development to accommodate other variation of the TDMS format will be attempted.

## November, 2020

- **Project Management and Administration (Task #1)**

  The monthly meeting was organized via Skype and the minutes were posted on the web page by the administrative staff. Monthly invoicing and payment to the sub-contractor has been managed by the staff. The project web site has been updated each month to reflect progress.

- **Field Laptop Computer (Task #2 & #3)**

  A rugged laptop computer has been procured and customized by installing the ParkSEIS-HMA (PS-HMA) software package to be used for field data acquisition and pseudo-real-time on-borad data processing purposes. It has an enhanced computing power, fast solid-state hard drive, embedded touch-screen capability, and sufficient RAM memory (16 GB) to meet the challenging demands. It has been used at Park Seismic to test the PS-HMA software developed to handle the 1D-array data and then shipped to Norrfee Tech for the 1st Joint Field Test (JFT) scheduled on December, 2020.

- **Hardware Development (16-Channel 1D-Array System) (Task #2)**

  The development of a 16-channel data-acquisition system by using MEMS microphones is under progress. Some circuit boards had to be re-designed to use new MEMS microphones as the old components have been discontinued. The new circuit boards are currently being constructed and the beta version of the 1D acquisition system will be ready for the Joint Field Test (JFT) soon.

- **ParkSEIS-HMA (PS-HMA) Software Package for 1D-Array Data (Task #3)**

  The ParkSEIS software package for this project (ParkSEIS-HMA) has been developed to perform the in-field operation of raw seismic data collected by using a 16-channel MEMS-microphone-array acquisition system that has been under development at Norrfee Tech. The algorithmic development that can properly handle different types of wavefields had been finished by the end of last month (October 2020) as summarize in this previous report. Therefore, the Graphical User Interface (GUI) part of the software has been developed and tested during this month as summarized in this report.

  Most components in the "IN-FIELD" module can perform the following tasks:

  1. Open a "New Project" for a new survey.
  2. Specify the folder where the raw TDMS data files are saved by the acquisition hardware system.
  3. Specify the folder where the TDMS data files (*.tdms) are converted and saved into ParkSEIS (PS) format (*.dat) for subsequent analysis by PS-HMA. All intermediate and final analysis results are also saved in this folder.
  4. Some recording-related parameters (e.g., sampling rate, number of samples, pre-trigger time, etc.) are set here and then passed into the acquisition-system control software installed at the PXI hardware system.
  5. Some parameters that can control the automatic detection and analysis of signal wavefields (e.g., surgical mute parameters, wavefield transformation parameters, etc.) can also be specified.
  6. Some parameters that can control visualization of the final results of the shear-wave velocity (Vs) and thickness (H) of the HMA layer can also be specified.
  7. Once "armed", it notifies the acquisition control software at PXI system to be ready for data collection.
  8. It detects new raw TDMS files being saved by the acquisition system, converts them into PS-format files, and then executes all planned data-analysis steps to finally display the results in a fully automated manner.

  All above steps are illustrated by using the Graphical User Interfaces (GUI's) in this report.

## December, 2020

- **Project Management and Administration (Task #1)**

  The monthly meeting was organized via Skype and the minutes were posted on the web page by the administrative staff. Monthly invoicing and payment to the sub-contractor has been managed by the staff. The project web site has been updated each month to reflect progress.

- **Hardware Development (16-Channel 1D-Array System) (Task #2)**

  The development of a 16-channel data-acquisition system by using ("new") MEMS microphones has been under progress at Norrfee Tech. The beta version of the 1D acquisition system (see photo) is ready for the Joint Field Test (JFT) soon. As soon as other peripheral components, such as cables, array-holding apparatus, impact-source device, etc., are ready, the 1st JFT will be executed sometime in January, 2021.

- **ParkSEIS-HMA Software Package for 1D-Array Data (Update and Improvement) (Task #3)**

  The ParkSEIS software package for this project (ParkSEIS-HMA) has been developed to perform the in-field operation of raw seismic data collected by using a 16-channel MEMS-microphone-array acquisition system that has also been under development at Norrfee Tech. The Graphical User Interface (GUI) part of the software has been summarized in a previous report. The documents describing communication between these GUI components and the hardware (PXI) system were previously sent to Norrfee Tech to optimally pass acquisition-related parameters to the PXI system as summarized in this file as well as in this appendix file. This communication part has been continuously modified and refined to meet various changes and updates made in the hardware (PXI) control software. The focus has been on the ability by the ParkSEIS software to notify the PXI system to "ARM" the system so that the acquisition-hardware system can collect data whenever the seismic source makes impact on the HMA surface. This effort has been summarized in this file. The first successful communication between the ParkSEIS and the PXI system had been accomplished via a lab test on December 4, 2020.

## PROGRESS BY TASKS AND NUMBERS

The entire work executed to accomplish the project goal is categorized into five (5) tasks (Tasks #1 – #5) as previously listed. In this report, the progress accomplishments made by both prime and sub contractors are described in the first 3 tasks (#1 – #3) by using the quantified indices used in the progress report form (Exhibit E in the project contract) submitted each month. These values are presented in tables on this page and then graphically displayed by using charts in the next page.

# Work Completed – Prime* Contractor

### This Period (%)

| Task | Previous Quarter (Q3-2020) | | | This Quarter (Q4-020) | | |
|---|---|---|---|---|---|---|
| | July | August | September | October | November | December |
| #1 | 7.7 | 6.2 | 5.4 | 4.2 | 3.8 | 5.8 |
| #2 | 0 | 0 | 0 | 0 | 0 | 0 |
| #3 | 3.8 | 3.1 | 3.4 | 5.3 | 5.3 | 2.8 |

### To Date (%)

| Task | Previous Quarter (Q3-2020) | | | This Quarter (Q4-020) | | |
|---|---|---|---|---|---|---|
| | July | August | September | October | November | December |
| #1 | 59.6 | 65.8 | 71.2 | 75.4 | 79.2 | 85 |
| #2 | 0 | 0 | 0 | 0 | 0 | 0 |
| #3 | 40.8 | 43.9 | 47.3 | 52.7 | 58 | 60.8 |

# Work Completed - Sub** Contractor

### This Period (%)

| Task | Previous Quarter (Q3-2020) | | | This Quarter (Q4-020) | | |
|---|---|---|---|---|---|---|
| | July | August | September | October | November | December |
| #1 | 12.5 | 10.0 | 5.0 | 2.5 | 2.5 | 2.5 |
| #2 | 3.8 | 2.2 | 8.1 | 8.1 | 10.1 | 13.5 |
| #3 | 13.3 | 0 | 0 | 0 | 20 | 0 |

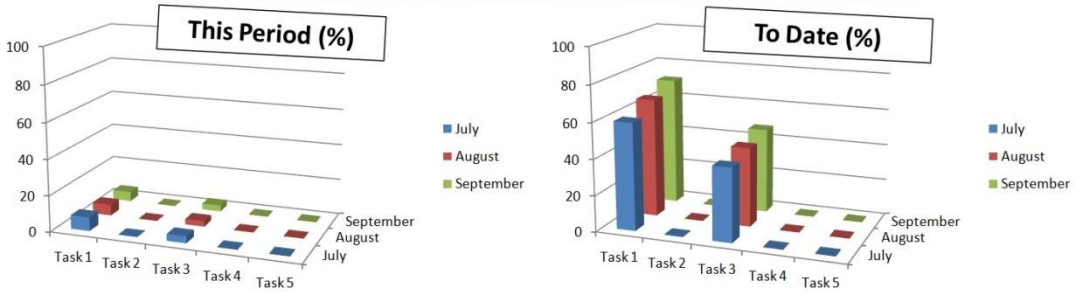
### To Date (%)

| Task | Previous Quarter (Q3-2020) | | | This Quarter (Q4-020) | | |
|---|---|---|---|---|---|---|
| | July | August | September | October | November | December |
| #1 | 67.5 | 77.5 | 82.5 | 85 | 87.5 | 90 |
| #2 | 15.8 | 18.0 | 26.1 | 34.1 | 44.2 | 57.7 |
| #3 | 33.3 | 33.3 | 33.3 | 33.3 | 53.3 | 53.3 |

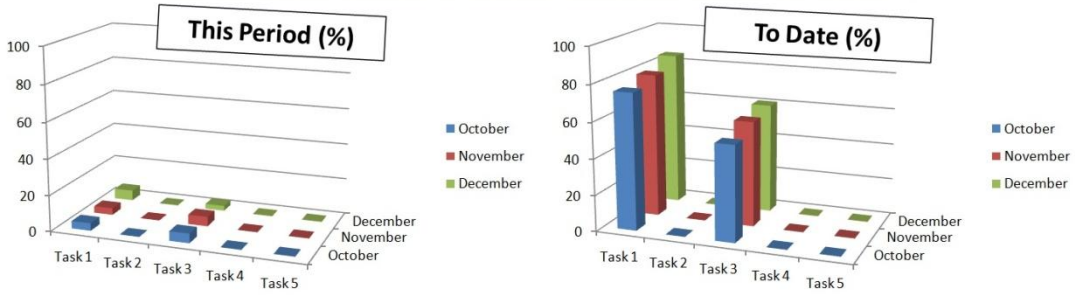
*Park Seismic LLC, **Norrfee Tech, AB

## Prime Contractor (Park Seismic LLC)

### Previous (3rd) Quarter (July – September, 2020)

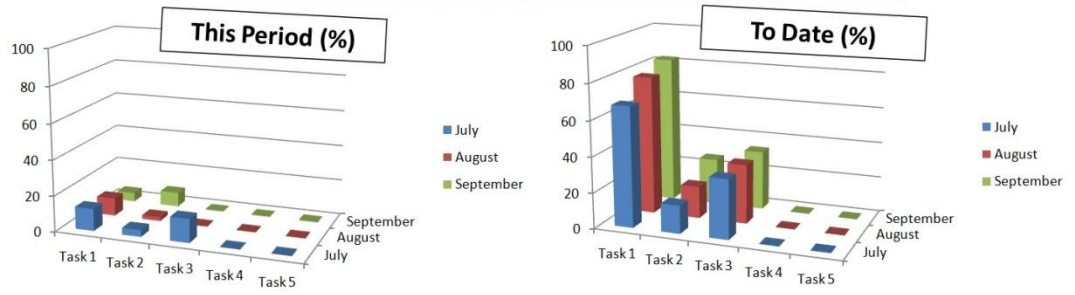



### This (4th) Quarter (October – December, 2020)

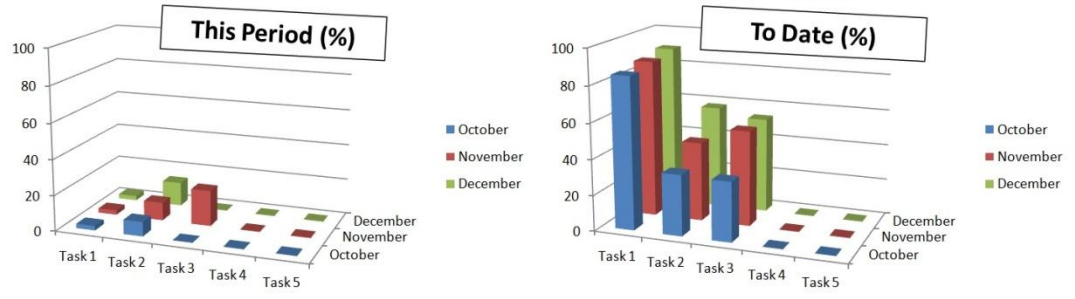



## Sub Contractor (Norrfee Tech, AB)

### Previous (3rd) Quarter (July – September, 2020)




### This (4th) Quarter (October – December, 2020)



# PROJECT PROJECTION

Projections made in the three tasks (#1 – #3) for the next three months (Q1-2021) are summarized below.

- **Task #1: Project Management and Administration**

  The 1st Joint Field Test (JFT) scheduled initially during the 4th quarter (Q4-2020) could not occur due to delayed hardware development progress. The delay was unavoidable due to the new COVID protocols imposed on the university duties with the developing investigator (Dr. Starkhammar). Currently, we are discussing an adjustment of the project schedule. On the other hand, both hardware (Task #2) and software (Task #3) developments have used more than 50% of allocated work hours by the end of the first year (Y1) (i.e., 57.7% for Task#2 and 60.8% for Task#3). This indicates the initial work schedule underestimated the number of work hours needed for Y1 to complete the 1D system (hardware and software). It is now projected to take about 65% of total hours to complete the 1D system. The completion of the 2D system is then expected to take a lesser amount of time than initially estimated (e.g., 35%, not 50%).

  Total hours for project management and administration (Task #1) used by the prime (Park Seismic) and the sub (Norrfee Tech) contractors during Y1 are 85% and 90%, respectively, exceeding significantly the planned 50%. Although it was necessary to spend a significant amount of time establishing new procedures and protocols at the beginning of the project execution (e.g., Q1 and Q2), it is expected a lesser amount of time will be necessary for the second year (Y2). Nonetheless, it seems necessary to use some hours from other tasks (#2 and #3) to execute this task (#1) during Y2.

  The COVID restrictions canceled travels scheduled initially in Q2 and Q4. One (Q2) was, and the other (Q4) is currently being replaced by virtual meetings. Consequently, this will free up some additional work hours and budgets to be available for personnel times in Tasks #2 and #3. This is currently under discussion among all investigators. We may draft the amended budget proposal and work schedule within the first quarter of Y2 (Q1-2021).

- **Task #2: Building 1D System for the 1st Joint Field Test (JFT)**

  The 16-channel hardware system is almost (e.g., > 90%) ready with the key component of the new-circuit-board MEMS microphone array built as shown in this photo. The remaining parts of the cables, housing apparatus, and the new impact device will soon be ready for the 1st Joint Field Test (JFT) to test the system through actual field surveys. The procedure will also include the ParkSEIS-HMA software package for the 1D system that will communicate with the hardware (PXI) control software and process field data sets in a pseudo-real-time mode. The JFT has now been re-scheduled to take place in January 2021. The virtual meetings will follow the field tests to discuss test outcomes.

- **Task #3: Software Development & Testing**

  During the JFT period, the environment of actual field survey will test the ParkSEIS-HMA (PS-HMA) package on several performing aspects such as communication between the hardware (PXI) system

and its control software, the performance of pseudo-real-time file conversion, automatic analysis, and display of output results. Development of the future package for the 2D system will use the field data sets collected during the 1st JFT as well as post-JFT field campaigns.