Methodological proposal of risk analysis in the quality control of seismic data - Application in the Amazon Basin

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Abstract

This paper suggests a methodology for implementation of the process of identifying and qualitative risk analysis for the Quality Control (QC) in seismic data acquisition. The result of the analysis is compared to the result obtained from the geophysical survey performed in the sedimentary basin of the Amazon, covering six programs (2D and 3D), with different characteristics and proportions.

Introduction

By definition, a project's characteristics are: temporality, progressive deployment and exclusive deliveries. The seismic datum, recorded during acquisition, is the exclusive product of the geophysical survey, whose project meets the definition and fits, as a perfect object, to the practices and routines of Project Management.

Project management is the application of knowledge, skills, tools and techniques to project activities in order to meet its requirements in the best possible way. Within the integrated processes, there is the Risk Management, which identifies, analyzes, creates answers and monitors project risks.

Risks management minimizes surprises and problems occurrences, reduces waste and increases the chance of success of the expected result. In the case of QC, the search is for the "perfect" datum without interference and distortion, which manages the improved handling and sharpens a more detailed picture, allowing clear and accurate interpretation of the subject matter. The paper presented here will be restricted to the identification and qualitative analysis of the risks inherent to QC, covering only part of the Risk Management.

The challenge of data without anomalies, or at least that meets the predefined minimum requisites of quality, is directly related to environmental characteristics and potential occurrences of negative impact over the acquisition. Based on unique characteristics of the medium, the systematic study of the risks will be conducted for further comparison with the reality found in the execution of the survey.

Survey Area Characteristics

The programs are located in the Amazon Basin exploration blocks in the AM-T-62, AM-T-84 and AM-T-85 whose bidding was in the eleventh round of biddings of the "Agência Nacional do Petróleo, Gás Natural e Biocombustíveis (ANP)" *[National Agency of Petroleum, Natural Gas and Biofuels].* 6 programs were deployed chronologically, being 3 with 2D technology and 3 with 3D technology, they are: 2D_1 Survey, 3D_1 Survey, 2D_2 Survey, 2D_3 Survey, 3D_2 Survey and 3D_3 Survey.

Geographically, the programs are in the eastern region of the state of Amazonas, about 200 km from the state capital, Manaus. The lines pass through six municipalities (Itacoatiara; Itapiranga; Nhamundá; São Sebastião do Uatumã; Silves and Urucará) and farming-agricultural areas. From the hydrographic point of view, the Amazon, Urubu, Anebá and Itabani, Madrubá, Uatumã, Maripá, Urucará Rivers and Canaçari Lagoon cut the whole area. These water bodies are influenced by the weather season and consequent regional rainfall (Figure 1). The measured altimetry levels range from 30 m to 120 m.

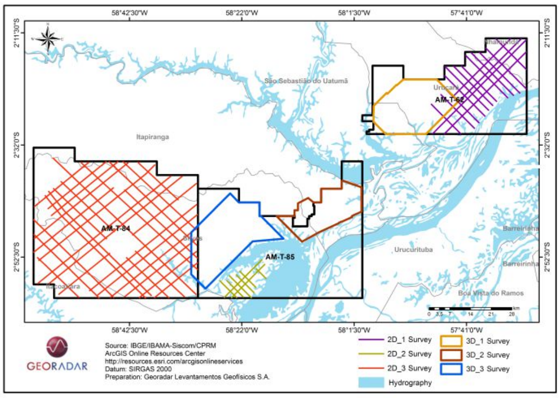

Figure 1 - Location map of surveys

The types of soil in the region are yellow soil of clayey, and the red yellow podzolic clayey dense forest environment with undulating to strongly wavy. Seismic programs are located mainly in areas with up to 25% of farming agricultural occupation and areas of predominantly Amazon jungle with urban areas and transition regions.

In Figure 2, we have the historical average rainfall, these curves were constructed from Weather Database information for Teaching and Research of the National Institute of Meteorology (BDMEP - INMET) - Weather Station from Manaus/AM.

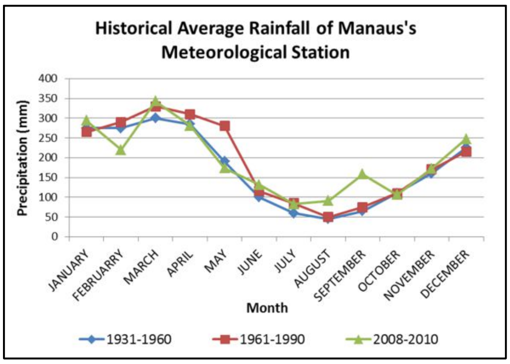

Figure 2 - Regional rainfall regime

The region has two distinct seasons: the rainy season (locally called the "winter"), from December to May, and the dry one (locally called "summer"), from June to November. Throughout the year, heavy rains of short duration usually occur.

Methodology

Risk management consists of own management planning processes, identification, qualitative analysis, quantitative analysis and planning responses to the risks. As mentioned, the paper will be restricted to the identification and qualitative analysis. The study results will be compared to the actual result of the project, focused on QC of the data.

Identification of risks

Risk is defined as an uncertain event or condition that, if it occurs, has a positive or negative effect on a project's objectives. The risk identification process aims to generate a list of risks that can threaten or create opportunities to project objective. It can be performed by composing analogy with previous projects, categorization and identification of new risks.

Taking into account that there is no history of previous projects and only the technical aspect of quality will be treated here (Figure 3), a methodology focused on the identification of new risks in the jungle environment was developed.

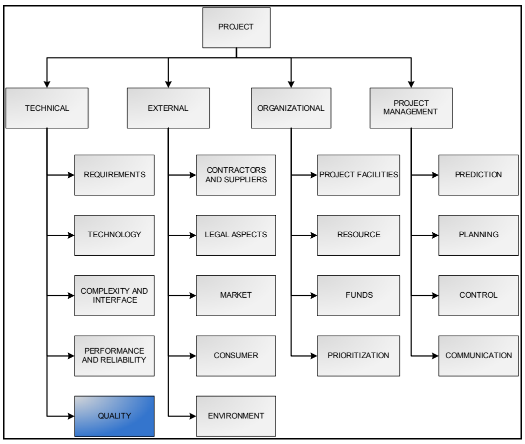

Figure 3 - Risk Analytical Structure

The operating planning of the acquisition and the information provided in the area of recognition of the region in order to detect factors that could impact the quality of seismic data were studied in this step. They are:

- Water mass with flooding channel modeling;
- Environmental Protection Areas;
- Engineering Works;
- Urban perimeter;
- Access Net.

The analysis of these aspects, plus the recognition of the area, led to the identification of possible dangers to the seismic datum, its causes and effects (Table 1).

Table 1 - Potencial Fail Identification

POTENCIAL FAIL	CAUSE	EFFECT	ROOT CAUSE
Poor quality record	Impossibility of survey accomplishment or seismic material scattering	Canceled traces	Property not released
			Environmental Protection Area
			Urban area
			Water bodies
	Sensor signal not detected	Dead traces (amplitude RMS = 0)	Urban area
			Water bodies
	Anomalous signal captured by sensor	Irregular traces (channels with anomalous amplitude, frequency higher than 60 Hz and excessive noise level below the first arrival)	Thunder and lightening
			Water bodies
		Noisy traces (RMS amplitude above the first arrival in the band from 8 μV to 10 μV)	Thunder and lightening
			Transmission line
			Urban area
Absence of records	Presence of natural or anthropic obstacle	SP in skip status	Water bodies
			Transmission line
			Urban area
	Area not released	SP canceled	Environmental Protection Area
			Property not released

Qualitative Analysis

Qualitative analysis is the process of assessing the probability and impact of identified risks, allowing prioritize them according to their potential effect on the project.

Making a study of the root cause and its incidence per program, possibilities of losses were estimated in the project, as shown in Figure 4.

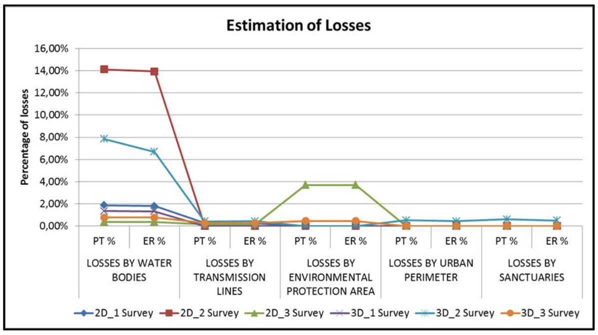

Figure 4 - Estimation of losses

Quantitative estimates in Figure 4 also were based on satellite imagery analysis and historical average rainfall in the region. The largest loss possibilities were associated to the water bodies, because the beginning of the survey was due for the rainy season and the grids of the surveys had significant part in the tributaries of the rivers that covered the area of some surveys (Figure 1).

For a qualitative evaluation of the probability of each risk, we used the scale described in Table 2, where each score corresponds to its description below. This scale should be prepared and studied in the planning step of risk management, noting the specific needs of the project and its implementation.

Table 2 - Classification of the probability

0.10	0.30	0.50	0.70	0.90
Very small	Small	Moderate	High	Very high
Seldom	Improbable	Possible	Probable	Very probable

Similarly to the probability, the scale of impact was obtained (Table 3).

Table 3 - Impact Rating

0.05	0.10	0.20	0.40	0.80
Very small	Small	Moderate	High	Very high
Unnoticeable	Noticeable under	Quality reduction	Unacceptable by client	Useless product

All risks identified were discussed and rated according to their probability and impact, based on Figure 4 and the experience of the team involved. Gathering all the information we obtain Table 4.

Table 4 - Impact and probability values of identified risks

			PROBABILITY					
EFFECT	IMPACT	ROOT CAUSE	2D_1 Survey	2D_2 Survey	2D_3 Survey	3D_1 Survey	3D_2 Survey	3D_3 Survey
Canceled traces	Moderate (0,20)	Property not released	0,1	0,1	0,1	0,1	0,7	0,1
		Environmental Protection Area	0,1	0,1	0,9	0,1	0,1	0,3
		Urban area	0,1	0,1	0,1	0,1	0,7	0,1
		Water bodies	0,5	0,9	0,1	0,3	0,7	0,3
Dead traces (amplitude RMS = 0)	Moderate (0,20)	Urban area	0,1	0,1	0,1	0,1	0,7	0,1
		Water bodies	0,5	0,9	0,1	0,3	0,7	0,3
Irregular traces (channels with anomalous amplitude, frequency higher than 60 Hz and excessive noise level below the first arrival)	Moderate (0,20)	Thunder and lightening	0,5	0,9	0,2	0,7	0,5	0,5
		Water bodies	0,5	0,9	0,1	0,3	0,7	0,3
Noisy traces (RMS amplitude above the first arrival in the band from 8 μV to 10 μV)	Moderate (0,20)	Thunder and lightening	0,5	0,9	0,2	0,7	0,5	0,5
		Transmission line	0,5	0,1	0,5	0,1	0,9	0,9
		Urban area	0,1	0,1	0,1	0,1	0,7	0,1
SP in skip status	Very high (0,80)	Water bodies	0,5	0,9	0,1	0,3	0,7	0,3
		Transmission line	0,5	0,1	0,5	0,1	0,9	0,9
		Urban area	0,1	0,1	0,1	0,1	0,7	0,1
SP canceled	High (0,40)	Environmental Protection Area	0,1	0,1	0,9	0,1	0,1	0,3
		Property not released	0,1	0,1	0,1	0,1	0,7	0,1

For prioritizing risks, we use the model of Probability and Impact Matrix (Table 5), where the product of multiplying the probability and impact display a range of priority of the item. The study and preparation of the matrix must also be accomplished in risk management planning step.

Table 5 - Matrix Probability x Impact

PROBABILITY					
0,9	0,05	0,09	0,18	0,36	0,72
0,7	0,04	0,07	0,14	0,28	0,56
0,5	0,03	0,05	0,1	0,2	0,4
0,3	0,02	0,03	0,06	0,12	0,24
0,1	0,01	0,01	0,02	0,04	0,08
IMPACT (QUALITY)	0,05	0,1	0,2	0,4	0,8

The colors of the matrix indicate the priority and the response from the risk:

- Green - passive acceptance risk; it can be assumed and does not require immediate response planning;
- Yellow - active acceptance risk, requires monitoring and planning of contingency actions;
- Red - unacceptable risk, mitigation plan, transfer or disposal immediately should be deployed.

By accomplishing respective multiplications and comparing them to matrix, the result presented in Table 6 is obtained.

Table 6 - Risks Prioritization

		PROBABILITY X IMPACT					
EFFECT	ROOT CAUSE	2D_1 Survey	2D_2 Survey	2D_3 Survey	3D_1 Survey	3D_2 Survey	3D_3 Survey
Canceled traces	Property not released	0,02	0,02	0,02	0,02	0,14	0,02
	Environmental Protection Area	0,02	0,02	0,18	0,02	0,02	0,06
	Urban area	0,02	0,02	0,02	0,02	0,14	0,02
	Water bodies	0,1	0,18	0,02	0,06	0,14	0,06
Dead traces (amplitude RMS = 0)	Urban area	0,02	0,02	0,02	0,02	0,14	0,02
	Water bodies	0,1	0,18	0,02	0,06	0,14	0,06
Irregular traces (channels with anomalous amplitude, frequency higher than 60 Hz and excessive noise level below the first arrival)	Thunder and lightening	0,1	0,18	0,04	0,14	0,1	0,1
	Water bodies	0,1	0,18	0,02	0,06	0,14	0,06
Noisy traces (RMS amplitude above the first arrival in the band from 8 μV to 10 μV)	Thunder and lightening	0,1	0,18	0,04	0,14	0,1	0,1
	Transmission line	0,1	0,02	0,1	0,02	0,18	0,18
	Urban area	0,02	0,02	0,02	0,02	0,14	0,02
SP in skip status	Water bodies	0,4	0,72	0,08	0,24	0,56	0,24
	Transmission line	0,4	0,08	0,4	0,08	0,72	0,72
	Urban area	0,08	0,08	0,08	0,08	0,56	0,08
SPs canceled	Environmental Protection Area	0,04	0,04	0,36	0,04	0,04	0,12
	Property not released	0,04	0,04	0,04	0,04	0,28	0,04

By the matrix, we would have to prioritize all information in red, starting from:

- Score 0.72
  - Skip caused by shot point (SP) located on water bodies in 2D_2 Survey;
  - Skip caused by SP located in transmission line area in 3D_2 Survey and 3D_3 Survey.
- Score 0.56
  - Skip caused by SP located on water bodies in 3D_2 Survey;
  - Skip caused by SP located in urban area in 3D_2 Survey.
- Score 0.40
  - Skip caused by SP located on water bodies in 2D_1 Survey;
  - Skip caused by SP located in transmission line area in 2D_1 Survey and 2D_3 Survey.

The concentration of unacceptable risks is clear in 3D_2 Survey, indicating that the program requires special attention.

Data acquisition

After the initial project steps, including planning, field survey was initiated. The rainfall behavior during the implementation period is shown in Figure 5. It is observed that the surveys carried out between October/ 11 to July/12 and November/12 to February/13 had more than 100 mm of rain in the months of its performance.

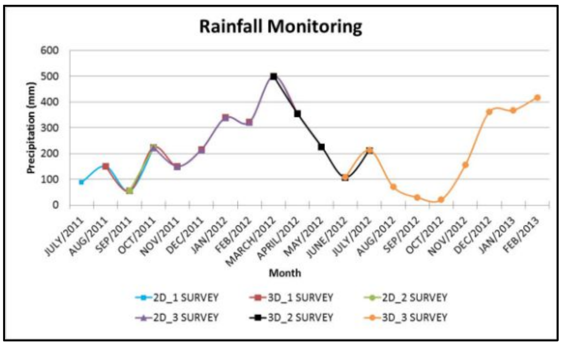

Figure 5 - Surveys rainfall monitoring

It is pointed out that during the execution of the project there were no anomalous periods in precipitation indexes when compared to the historical average for the region and the trend of rainfall over time expected for the region of the surveys.

The surveys that used 3D seismic technology occurred during periods of rain and drought. 2D seismic surveys were carried out in dry periods, except for the 2D_3 Survey that, due to its greatest extent, lasted until the rainy season in the region. Therefore, the remarks in relation to rainfall analysis performed in the risk identification phase remained valid.

Operationally there were no significant barriers which intervened in the quality of the datum that required special treatment.

As a procedure for the acquisition, the acquired data in each step went through a quality analysis that defined if that datum could follow to a later step. The acquired data by the Permitting should meet the area of recognition and should also specify macro obstacles identified by field visits.

The Topography front used the information from Permitting to make the realization of the points and the survey of their coordinates. At this step it was possible to assign a description to each SP and Receiving Station (RS), stating which the characteristics of the area were. The topographic data were validated as quality criteria and a report of the points was produced that made up the survey and their status, *e.g.* not materialized point (reason: water bodies, house, urban area and Environmental Protection Area).

The drilling / charging / blasting works followed the same flow of the above fronts, analyzing the quality of the acquired data and ending with the general summary of the issues identified throughout the survey. There was a subsequent treatment for the quantification of all the occurrences.

The acquisition was completed regularly, starting phase of the study of the recording quality statistics.

Validation criteria of seismic records

For the study of the resulting data from the survey, validation criteria for acceptance of the data that the traces that made up one SP could not be adopted:

- Over 10% of the active spread with Ambient Noise greater than 8 microvolts or 10 microvolts depending on the area;
- Over 10% of the active spread with problem of irregular traces;
- The sensor problems (tilt, leakage and resistance) could not exceed 2% of the active spread; and
- Traces with "zero" amplitude, called "dead", could not exceed 2% of the active spread.

The traces were analyzed and rated as shown in Figure 6.

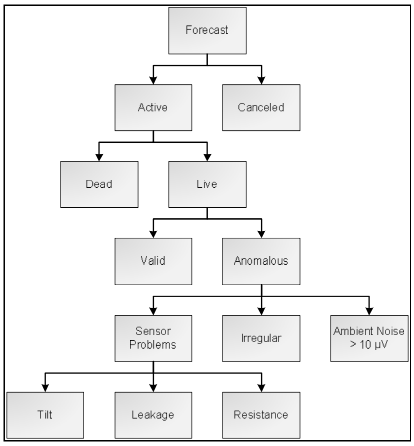

Figure 6 - Adopted rating for traces

As it can be seen, besides canceled traces, dead, irregular and noisy, other occurrences were detected:

- Traces with Sensor Problems:
  - Leakage - global leakage resistance between the channel and the medium out of the threshold value of 5 MΩ;
  - Tilt - sensor incorrect tilt, out of the 5% limit value;
  - Resistance - resistance of the seismic sensor connected to the channel input out of the reference range from 500 Ω to 550 Ω.

Shot Points Rating

The SP of surveys were discretized according to the rating presented in Figure 7, according to the adopted model in the risk identification step.

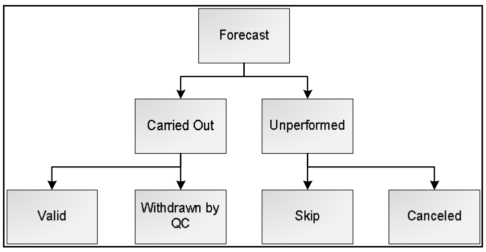

Figure 7 - Adopted rating for Shot Points

In a final check, the QC separates data that were not classified as valid. This happens when a SP has some kind of problem that had not been discarded along the process before.

Results

Statistical Analysis of the Records Problems

The map with the resulting geographical distribution can be seen in Figure 8. The map is a representation of the concentration of occurrences. It is important to note that some effects were relevant in some surveys but not concentrated, which did not make it possible for them to be represented on the map. Beside this it can be observed in the figure that:

- The Ambient Noise and "dead" traces were a recurrent problem in all surveys;
- Irregular traces occurred in 2D_1, 3D_2 and 3D_3 Surveys;
- The 3D_1 and 2D_2 Surveys presented a traces concentration with sensors problems, specifically tilt, which was not diagnosed in the other surveys.

Now evaluating in separated numbers, the values for each occurrence per program were compiled in Table 7 and compared to the result of the qualitative analysis of the risks.

Table 7 - QC Statistic Analysis

OCCURRENCE	2D_1 Survey	2D_2 Survey	2D_3 Survey	3D_1 Survey	3D_2 Survey	3D_3 Survey
Canceled traces	7,91%	5,59%	7,09%	7,40%	20,24%	8,74%
Dead traces	2,62%	2,13%	0,61%	1,95%	8,52%	3,18%
Irregular traces	1,15%	0,37%	0,77%	0,54%	3,45%	0,65%
Noisy traces	3,74%	2,81%	2,09%	1,63%	1,95%	1,19%
Tilt	0,61%	0,30%	0,78%	0,56%	0,56%	0,38%
Leakage	0,10%	0,02%	0,12%	0,11%	0,05%	0,04%
Resistance	0,26%	0,19%	0,26%	0,30%	0,21%	0,18%
Skip	1,81%	1,61%	1,77%	2,46%	13,88%	4,20%
Canceled Shot Points	2,17%	0,21%	1,99%	0,00%	0,73%	0,00%

IDENTIFIED AND PRIORITIZED
IDENTIFIED AND NOT PRIORITIZED
NOT IDENTIFIED

The methodology presented was able to identify and prioritize part of the interferences in the quality of the records, including the peaks of canceled traces and skips (20,24% and 13,88% in 3D_2 Survey).

There have been cases where the risk has been identified, but not all its root causes. An example was the incidence of noisy traces caused by strong winds in 2D_1 Survey and 2D_3 Survey. Moving people and animals over some areas have also contributed to the dead traces, a root cause that was not pointed out at the identification step.

The most remarkable case of the comparison is found in the occurrence of canceled traces. The score of the impact times the probability of its causes, independently, has not classified the risk as a priority. However, the problem was significant due to the occurrence of all events combined, indicating that the analysis should also cover the joint possibilities.

In the end, tilt, leakage and resistance were problems not pointed out at the identification process. The occurrences did not go over 1%, but could be more, depending on the project.

Results discussion

The methodology has been useful to Risk Management in relation to the steps for identification and qualitative analysis. Part of the problems were forecast and prioritized. Both these problems as those which were only identified after the acquisition can and should be recorded as history for future analyzes. This exercise already validates the proposed application.

Including other sources than those mentioned, as the previously acquired data reprocessing, the analysis of the elevation profile of the region, the study of the soil use and occupation is suggested to improve the identification process. The richer the sources, the greater the chances of identifying potential failures and causes. It is also recommended to try to anticipate possible problems caused by the operation for acquisition, such as noise caused by work fronts close to the lines on record.

The next steps in the Risk Management consist of quantitative analysis, in preparing the response plan and risk monitoring. If all this methodology had been properly performed prior to the execution of the acquisition, the risks could have been previously mitigated and surely there would be a positive impact on the losses of record quality.

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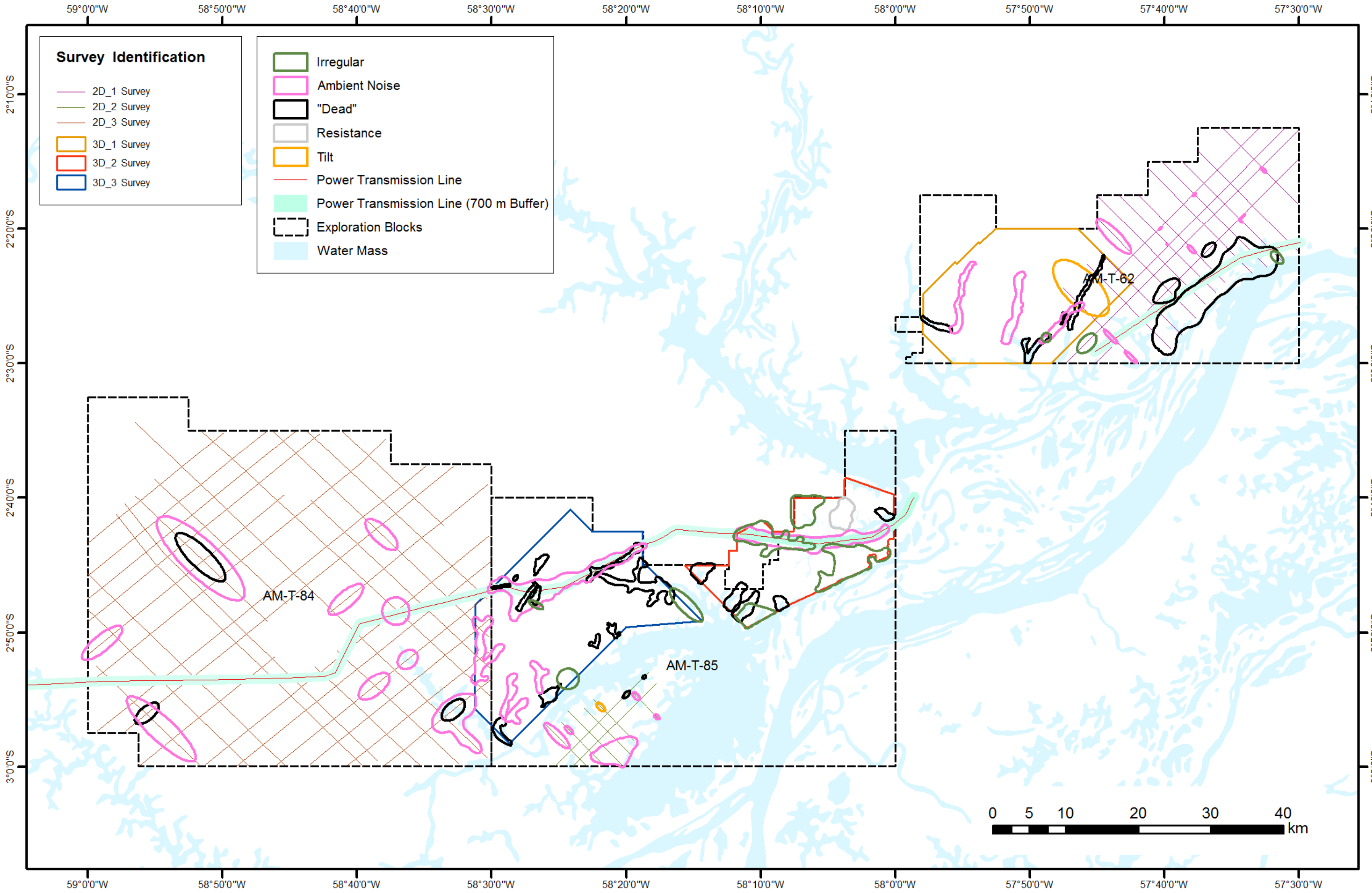

Figure 8 - Results mapping of acquired data Quality Control