ANALYSIS OF FLUVIAL SYSTEM PARAMETERS IN THE PATTANI BASIN, GULF OF THAILAND

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ABSTRACT

The purpose of this study is to predict reservoir geometries , to study of the relationship of fluvial channel parameters and to optimize drilling locations within the Miocene fluvial systems which are the main productive oil and gas reservoirs in the Gulf of Thailand. However, it hard to predict reservoir geometries in the Miocene section due to poor seismic resolution whereas the Pleistocene to Recent seismic section has excellent resolution properties. For this reason this study measures the extensive channel parameters in the shallow section to be used as analogues for the deeper targets. 3D seismic plan view images of horizon slices as well as satellite images of modern fluvial systems were interpreted and channel parameters from 42 channels were used to study the relationship between fluvial channel wavelength, channel width and channel sinuosity. The modern fluvial systems included the Chao Phraya and Ping rivers. The shallow 3D seismic from 90 ms to 300 ms TWT showed channels and point bars which were clearly imaged. The deeper 3D seismic data which was used to incorporate shallow well log data in order to correlate point bar thickness was less reliable for its seismic resolution . Previous studies have suggested that there is a good relationship between key fluvial parameters such as channel wavelength, width and point bar thickness but this study came up with less conclusive results. The results found that there is a wide range in channel parameters even within similar systems. Fluvial geometries are controlled by many factors and it is difficult to develop any fixed relationships between the various parameters. However, channel width versus wavelength does show a link although the correlation coefficient is quite low. The lack of determining any clear relationships between the fluvial parameters is in part due to poor measurement capabilities, particularly in the deeper seismic data set.

Keywords: Pattani Basin, Channel parameters, Channel parameter relationships, Fluvial systems

1. INTRODUCTION

This research is a study of the relationship of fluvial channel parameters from a data set in the Gulf of Thailand. These data provide the opportunity to measure the dimensions and geometries of the sand bodies in the Pleistocene to Recent section. The fluvial systems are characterized predominantly by moderate to high sinuosity single-channel systems with side attached point bars (Reijenstein et al., 2011). Previous work has documented the dimensions and volumes of these systems and the relationship of channel parameters in the very shallow section using 3D seismic data only. This study looks at this shallow data set as well as a deeper seismic data set which incorporates well logging data to assess some of the previous documented relationships. Sand thickness from well log is more reliable than seismic data and is much better in terms of representing real data and more accurate data. Moreover, this study looks at several different data sets; the modern systems onshore Thailand, the shallow seismic as in previous studies, and the deep seismic data incorporated with well log data, to see if there is any significant difference in the relationships compared to previous studies. If good relationships can be determined then channel parameters may be more easy to predict in the deeper main productive section.

2. METHODS

In the shallow seismic section 21 horizons were interpreted every 10 ms from 20 ms below sea floor to 300 ms using Seisworks software. This section doesn't dip much so a flat horizon slice represents an approximate chrono-stratigraphic surface. In the deeper seismic section one main horizon was interpreted which is the clearest reflector in this section. Then 23 sub-horizons were created every 20 ms parallel to this main horizon from around 500 to 1,000 ms using Seisworks software.

The Root Mean Square (RMS) attribute was used for amplitude extraction. RMS is a statistical al measure of the magnitude of variation within the dataset and is especially useful when variations are both positive and negative. In the shallow seismic section 21 RMS amplitude extractions along the stratal slices were made using Seisworks software. The amplitude extraction was calculated within a 5 ms interval above and below the picked horizons. For the deep seismic section 23 RMS amplitude extractions along the stratal slices were made using Seisworks software. The amplitude extractions were calculated within a 10 ms interval above and below the picked horizons.

For the well log data, sand intervals were interpreted from shallow logs around 300 to 900 m based on gamma ray, resistivity and neutron density cross-over logs using Stratworks software. After the sands were identified they were correlated to point bars which had been identified in multiple time and stratal slices using Seisworks software. The seismic section view and horizon amplitude extractions were used to interpret these features.

After that, channel parameters were measured on all three data sets. These included thickness, channel width, channel wavelength (full wavelength) and channel sinuosity (Figure 1). for each channel system measured on the seismic and on the satellite images. Fifteen measurements were made for each parameter. These were then statistically averaged and a median value calculated. The median is more represent ative of the most data and it represents the highest probability of the numerical value distribution. With this information plots of channel parameters were made in graphs and Box Whisker plots to show the statistical ranges. Cross-plots were then made between channel width, wavelength and sinuosity relationships. The deep seismic which incorporated the well data from shallow wells allowed the interpretation of sand thickness.

3. RESULTS

Channel width, ranging from 52-586 m. was measured from forty channels in three data sets show in Figure 2. The biggest channel width observed was in the shallow seismic data set and the smallest channel width

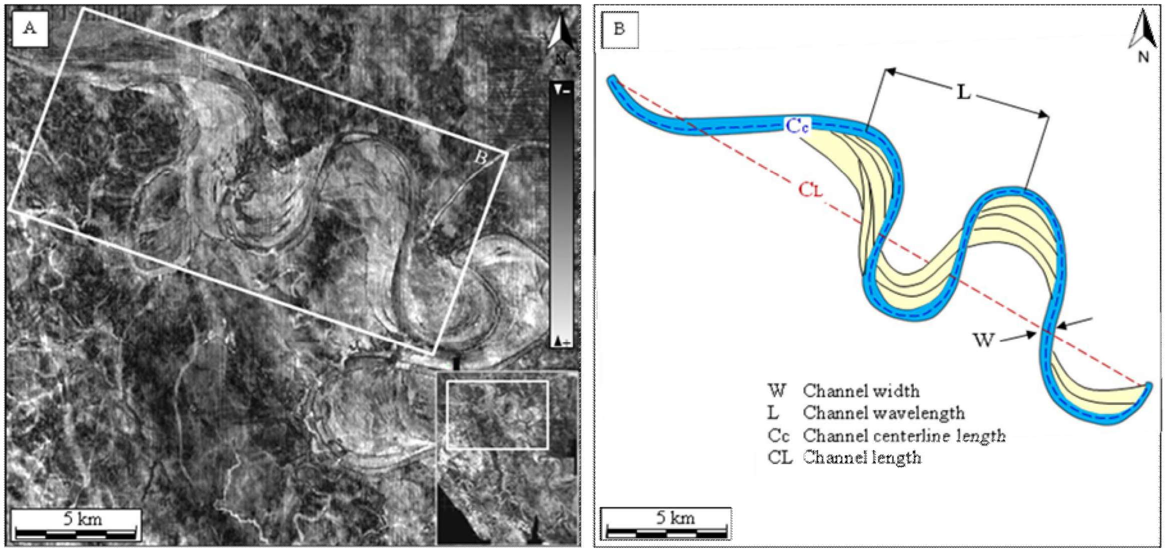

Figure 1. (A) A seismic horizon slice at 160 ms showing the clearest channel in the shallow data set (B) The variables used to describe channel parameters in plan form.

was from the upper reaches of the Ping River. The biggest variations were observed in the modern river systems. The error in measurement for this parameter increased in the seismic and the deep seismic data sets. The channel belt is sometime very similar to channel width on seismic time slices in the deeper images so have to be careful in separating the genetically different geomorphic features seen in the same 3-D time slices

For the **c**hannel wavelength the same analysis was done using the three different data sets, ranging size from 204-14,896 meters. Channel wavelength was quite variable, as shallow time slice wavelength varies from 500 m to 5 km in this one time snapshot. Channel wavelength ranged from 204-14,896 m, in the forty channels measured in three data sets. For each channel, 15 channel width measurements were taken and their statistical distribution graphed. The longest channel wavelength was observed is in the shallow seismic data set and the shortest channel wavelength was observed in the shallow seismic data set also. The cause of error for measuring this parameter accurately is two folds. Firstly, for some of the channels it is hard to see the trough and peak particularly in the deep seismic data set where you can see just some parts of channels. Secondly, some channels have high sinuosity and it is hard to see the channel wavelength as there are two small peaks or troughs close together in sometimes small and narrow channels. Also the troughs and peaks can be very subtle.

Sand thicknesses of point bars were measured from the shallow log data ranging in depth from 300 to 900 m. The range of values measured from 13 shallow logs is 4-13 meters. It is often hard to measure their thickness accurately as they are not pure clean sands. The fluvial systems in the shallow Pattani Basin are very fine grained and are not clean so it is difficult to estimate top and base of these sandy intervals. Sand thickness was interpreted from lower gamma ray, higher resistivity (gas or oil) and lower density values when compared to shale properties. Also, it is important to realize the variability of thickness in a point bar deposit. For example, Labrecque (2011) explains the difference of sand thickness from well to well. It depend on where the well is drilled. Channel sinuosity ranged from 1.06-3.21 which was observed in forty-two channel

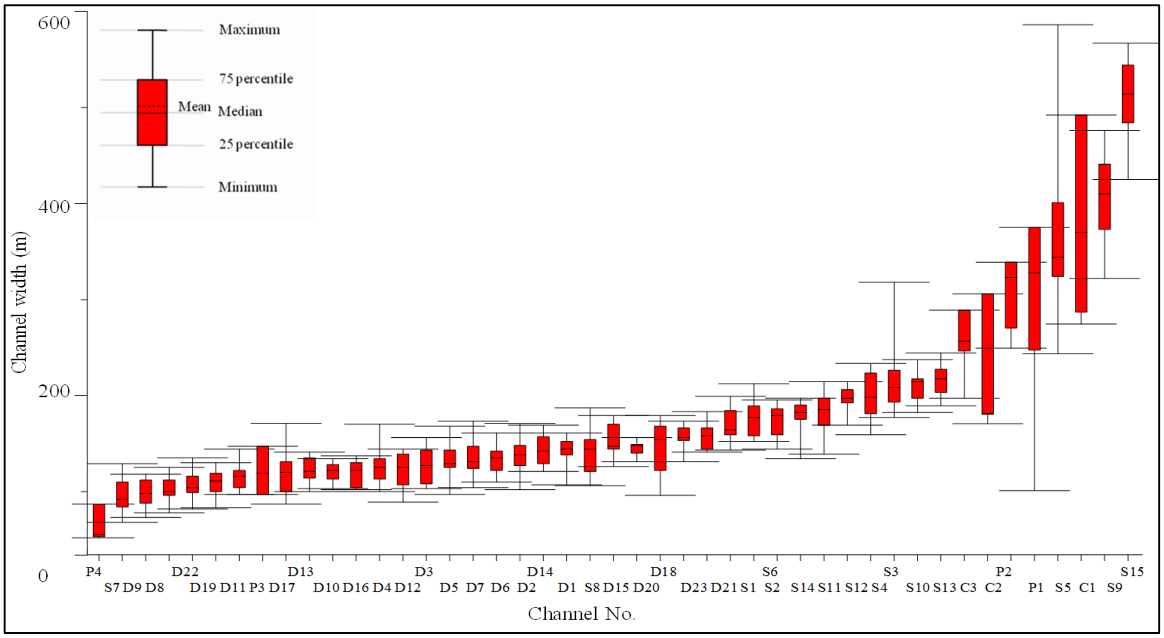

Figure 2. The box whisker plot of channel width for all three data sets. There are 40 channels ranging size from 52-586 meters.

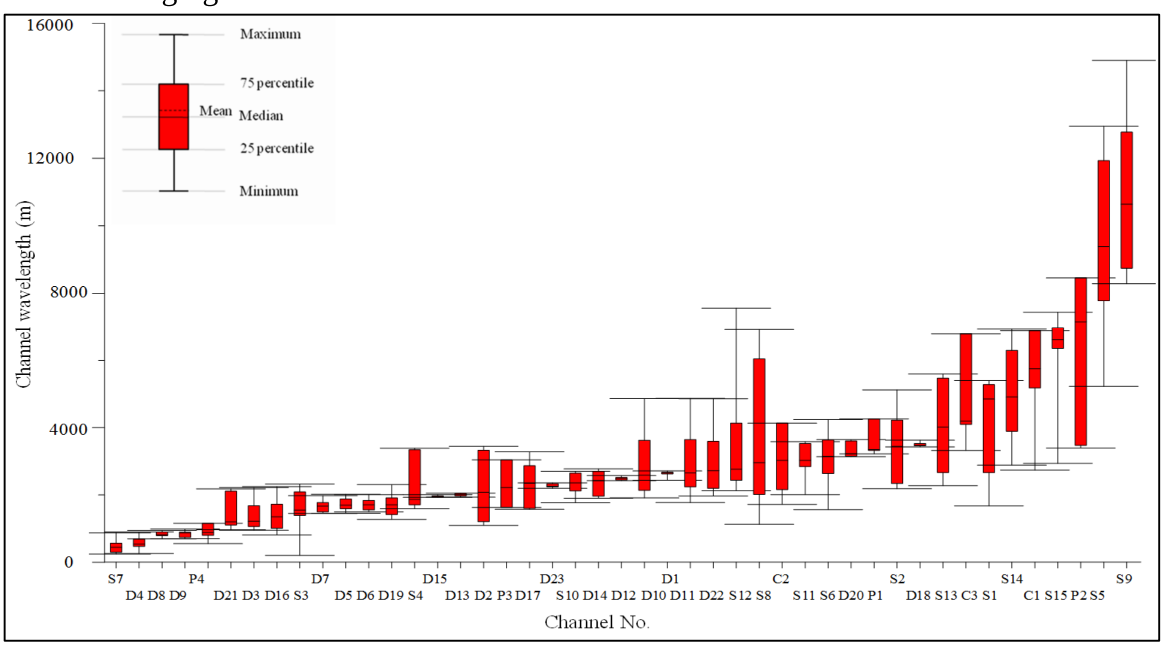

Figure 3. The box whisker plot of channel wavelength for all three data sets. There are 40 channels ranging size from 204-14,896 meters.

sinuosity is defined as the channel length divided by channel centerline length. The error for this parameter increases in the seismic and the deep seismic data sets. The channel sinuosity is sometime hard to see in the small channels and the deeper images so have to be careful in separating the genetically different geomorphic features seen in the same 3D time slices.

CHANNEL PARAMETER RELATIONSHIPS

A Good relationship exists between channel wavelength and channel width particularly in the modern and shallow seismic data sets. This is likely due to the fact that channel width was more accurately defined in these two data sets. In comparison, the regressive correlation coefficient for the deep data set is poor.

A poor relation exists between point bar thickness and channel wavelength and channel width. The linear trend line of point bar thickness from previous studies is 17 times to channel width and ~233 times to channel wavelength but the correlation in this study is almost non-existent. The data in this plots has significant error from thickness measurement as it is very fine grained and are not clean, also the deeper seismic section was so difficult to measure as low resolution.

A poor relationship was observed between channel sinuosity and channel width and channel wavelength. This is consistent with other studies e.g. Reijenstein et al., (2014). Sinuosity can be highly variable even within one channel over a relative short reach of the fluvial system. This study found a range of channel sinuosities from 1.06 to 3.26 which can interpreted as typical of sinuosity and meandering channels.

4. DISCUSSIONS

Previous workers have shown that fluvial geometries are controlled by many factors and that it is difficult to develop any fixed relationships between the various parameters. In the case of channel width, for example, there can be a variety of channel widths along any one channel at the same time. The reason is that meander geometry is not only related to channel width (which correlates with discharge) but also to sediment load, slope and boundary materials. Ranges of physical characteristics related to different meander bend types can be summarized by a schematic of cross-sectional geometries and dimensions through a meander.

In summary, there are many local variables which affect channel width.

Channel wavelength and channel sinuosity can also be just as variable, even when deposited at the same time in the same section. Flow characteristics (turbulence and secondary or lateral currents) are highly variable and they lead directly to the development of a sinuous channel (Thorne, 1997). There are also a lot of variations in point bar thicknesses and styles. Measuring point bar thickness from well data is a problem because these data only show the apparent thicknesses of the channel objects. Sometimes the thicknesses are too small because the well intersects the channel at the edge and sometimes the thicknesses are too large because channels are stacked (Guo, 2010).

Channel parameters also vary a lot depending on the style of the river system. For example in study area three channel styles were found which could be compared with the bends in the Red River data set which have been classified as one of three types based on Brice (1975) classification system. These are equi width meanders, denoted as Type e meanders; meanders with point bars, denoted as Type b meanders; and meanders with point bars and chute channels, denoted as Type c meanders.

In summary, the variety of channel styles affects the variety of channel parameters which include discharge, slope, sediment grain size and load, channel-margin composition and strength, and factors related to the local geological history; they are the subject of a vast literature data base

The result of this study is consistent with these findings and has come up with a high range for each channel parameter. However there are some observations to comment on. The channel parameter relationship between channel width and channel wavelength is quite a good relationship. It is the most reasonable trend line from this study (correlation coefficient of 65%) with channel wavelength scaled to ~17 times the channel width but there is still a wide spread in the data (maximum, minimum). It is worthwhile to compare this to previous studies in the Quaternary/Pleistocene rivers of the Gulf of Thailand from Feng, (2000) and Posamentier et al., (2014). Feng got a channel wavelength scaled to ~ 10 times the channel width whereas a channel wavelength scaled to ~30 times the channel width was determined by Posamentier et al. (Figure 4).

Previous studies from other countries (e.g. Leopold et al., 1964) show a channel wavelength average about 11 times the average channel width which is commonly used. They recognize that the range could be between channel wavelength 10-20 times of channel width. Others (e.g. Yalin, 1992) have suggested channel wavelengths about 6 times the channel width. The comparison of the relationship between Thailand data and other countries is quite varied (Figure 5).

The channel parameter relationship between channel width and point bar thickness determined in this study is quite poor (Figure 6). The data points are quite spread out and channel width is scaled to ~17 times the point bar thickness but the correlation factor is extremely poor.

Previous studies in the Gulf of Thailand by Feng (2000), Samorn (2006) and Posamentier et al (2014) determined channel width scaled to ~17 times, ~19 times and ~17 times point bar thickness respectively, with some excellent correlations. This comparison of the relationship between Gulf of Thailand data sets shows low variability even in the same time interval in the shallow Pleistocene section (Figure 4). However, there are some studies from Gibling (2006) for example which shows that this relationship has only a broad correlation. Lambiase, (pers. comm., 2014) showed that there is no relationship between channel width and sand thickness; thickness to width ratios are meaningless in a predictive sense. Sand thickness depends more on the rate of sand supply versus the rate of change in accommodation space.

The channel parameter relationship between channel width and channel sinuosity from this study shows a poor relationship. There is no real correlation coefficient which highlight the difficulty in predicting sinuosity on the basis of point bar thickness or river size and vice versa. This result is similar to other studies e.g. Posamentier et al (2014). Rivers exhibit continual changes in their channel length sinuosity that result in maintaining a gradient such that the stream system doesn't degrade or aggrade. For example, when the gradient of the rivers increases, by reducing natural sinuosity the reach length is decreased, increasing the local slope and creating a series of channel adjustments (Rosgen, 1996).

In summary, these results are not surprising as in the natural system there are rarely perfectly linear or straight systems (United States Department of Agriculture, 2007). As can be seen in this study, there are a variety of relationships. In each channel parameter and most previous studies (United States Department of Agriculture, 2007) suggest that trend lines can be used only as rough estimates but it should only be used with caution. It is difficult to determine the relationship between any two parameters for different geo bodies deposited in different environments.

Previous studies from Feng (2000) and Samorn (2006) as well as this study suggests that the uppermost section of the Gulf of Thailand shelf is Pleistocene in age and has continental-scale fluvial systems imaged throughout the data set which have the same order of magnitude as the modern Chao Phraya River system (Reijenstein et al., 2011).

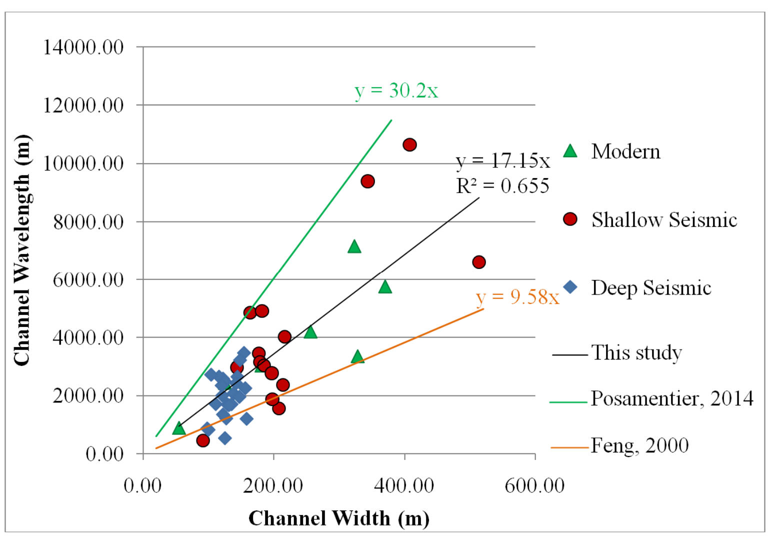

Figure 4. The graph showing comparison between channel width versus channel wavelength in Thailand from this and other studies.

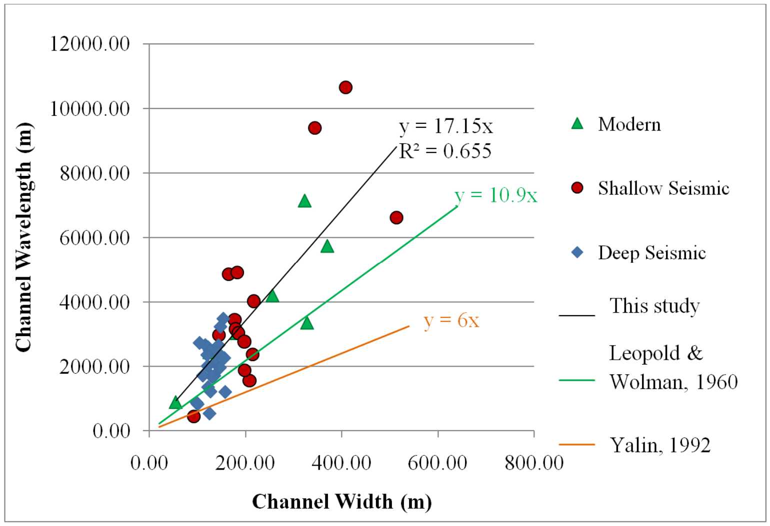

Figure 5. The graph showing comparison between channel width versus channel wavelength in Thailand (this study) and other countries

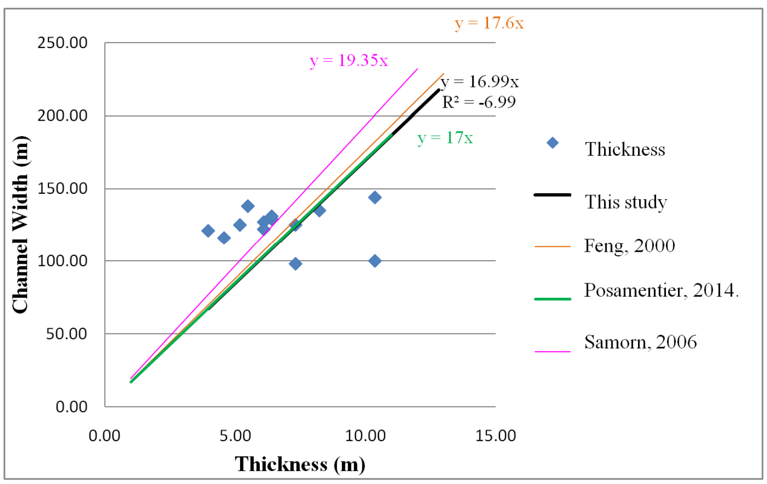

Figure 6. The graph showing comparison between channel width versus point bar thickness in Thailand from various studies of Pleistocene to Recent interval

The Chao Phraya data set is close to the mean trend line suggesting that depositional systems the modern have very similar characteristics at least to the Plio-Pleistocene fluvial systems. The deeper seismic data set does appear to have different fluvial characteristics compared to the shallow and modern data sets. Any similarities of depositional style before that needs to be studied further.

CONCLUSIONS

1. It is difficult to predict any precise relationships between reservoir geometries in fluvial systems. There are many variables that control channel parameters such as discharge rate, slope, sediment grain size and load, channel-margin composition, strength, sea level variations, factors related to the local geological history and human activities,

so the range of channel parameters will show a broad distribution.

2. Well log data (sand thickness) is more reliable than seismic data for measuring point bar thickness. However, there are still some uncertainty because sands are very fine grained in the shallow section and are not clean so it is difficult to estimate top and base of these sandy intervals.

3. Previous studies in the Gulf of Thailand (e.g. Posamentier, 2014) have suggested an excellent correlation exists between channel wavelength, channel width and point bar thickness in the shallow Pleistocene to Recent interval. This study could not verify this claim with such certainty.

4. In natural systems there are rarely perfectly linear relationships between parameters. As can be seen in this study, there are a variety of uncertainties in the measurement of each channel parameter. This study suggests that all trend lines can used as rough estimates but it should only be used with caution if applied universally.

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