# Groundwater Level Prediction at a Pilot Area in Southeastern Part of the UAE using Shallow Seismic Method

Murad A, Baker H, Mahmoud S, Gabr A

***Abstract*****—**The groundwater is one of the main sources for sustainability in the United Arab Emirates (UAE). Intensive developments in Al-Ain area lead to increase water demand, which consequently reduced the overall groundwater quantity in major aquifers. However, in certain residential areas within Al-Ain, it has been noticed that the groundwater level is rising, for example in Sha'ab Al Askher area. The reasons for the groundwater rising phenomenon are yet to be investigated. In this work, twenty four seismic refraction profiles have been carried out along the study pilot area; as well as field measurement of the groundwater level in a number of available water wells in the area. The processed seismic data indicated the deepest and shallowest groundwater levels are 15m and 2.3 meters respectively. This result is greatly consistent with the proper field measurement of the groundwater level. The minimum detected value may be referred to perched subsurface water which may be associated to the infiltration from the surrounding water bodies such as lakes, and elevated farms. The maximum values indicate the accurate groundwater level within the study area. The findings of this work may be considered as a preliminary help to the decision makers.

***Keywords*****—**groundwater, shallow seismic method, United Arab Emirates

## I. Introduction

SEISMIC refraction has been adapted in this work to investigate the groundwater in a pilot area nearby Jabal Hafit in the southeast of the UAE. At the present work, groundwater level and structure framework of the area were systemized. Measured water levels for the available wells were used as control points. The results of these measurements were used to confirm the assumption that the groundwater level can primarily be revealed by seismic refraction in the gravely-sands or silty clay areas.

The groundwater level can be determined as a boundary of acoustic impedance by seismic refraction method [1]. When the electric properties of nearsurface sand and clay beds are investigated, a principal obstacle is recognized in applying the method of resistivity measurement to problems of water exploration. Namely, the dissociated ions of adhesive water, being an electrolite, in the case of both sand and clay give a relatively good electric conductivity even to the "dry" ground, which will not be significantly altered by the saturation of the pore volume by groundwater. Regardless of several exceptionl cases, the groundwater level does not behave as an electric boundary and it can not be located by the method of resistivity measurement. The possibility of using the seismic refraction method is determined by the elastic properties of the nearsurface layers [1].

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## II. Geological Setting

The study area is situated in Al-Ain; in the eastern part of Abu Dhabi - UAE near the border with sultanate of Oman and at the western margin of the northern Oman Mountains (Figure 1). Although Al-Ain is located within an arid desert belt of the world and characterized by drainage net that formed as a result of the prevalence of humid climate during the Quaternary [2]; it is considered to be one of the largest and ancient oases of the Arabian Peninsula due to the fresh groundwater supply which is derived from the Oman Mountains to the east.

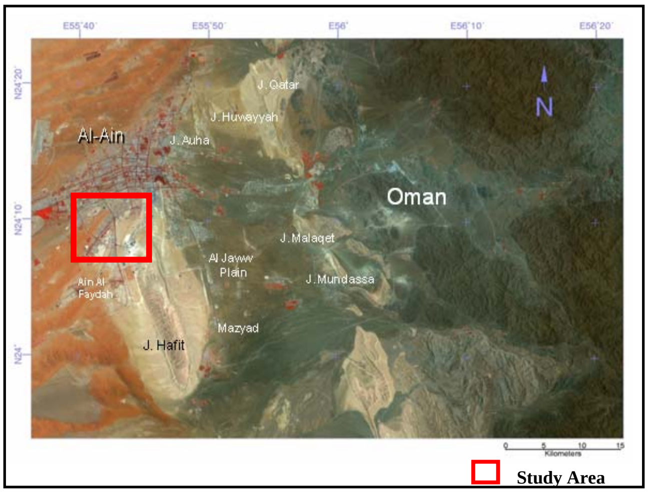



Fig. 1 Sattelite image showing locations of Al-Ain , Jabal Hafit , and the study area

The geomorphic units in Al-Ain area are classified as mountains, gravel plains, drainage basins, sand dunes, interdune areas and inland sabkhas. The main mountains in Al Ain area are Jabal Hafit, Jabal Moundassah, Jabal Malaqet, Jabal Al-Oha and Jabal Rawdah. Jabal Hafit is considered as one of the most prominent features of the area, it is located to the southeast of Al-Ain city between latitudes 24$^o$ 00' and 24$^o$ 13' N and between Longitudes 55$^o$ 44' to 55$^o$ 49' E. It is a Tertiary anticlinal structure with approximately 29 km length and 5 km width with a maximum elevation of about 1160 m above the sea level. It plunges to south-east in Oman and north-west in UAE [2]. It is bounded to the north by Al-Ain city, to the east by Al-Jaww plain, to the south east by Mazyad, to the south by Oman and to the west by Ain Al Faydah and Zakher. Jabal Hafit is an eroded anticline, with limbs dipping to the east and west. The overall morphology of the mountain gives it a “whaleback" appearance. The limestone and marls exposed in Jabal Hafit are considered of Lower, Middle and Upper Eocene age. To the east, it is bounded by Al-Jaww plain and Oman Mountains.

The gravel plains occupy the area between the Oman Mountains to the east and sand dunes to the west. The gravel plains consist of alluvial sand and gravel transported by wadis dissecting the Oman Mountains. The continuity of these plains is locally interrupted by sand dunes which covered about 75% of the total area of UAE [3]. The stratigraphy of Al-Ain area comprises mainly of a sedimentary sequence ranging in age from the Cretaceous to the Quaternary [2], [4] & [6]. Most of Al-Ain area is covered by Quaternary deposits that consist of near-surface and surface sediments of mixed alluvial and aeolian origins, together with some much localized sabkhas.

## III. METHODOLOGY

Twenty five Seismic refraction profiles have been acquired in the study area. A number of profiles with 60 m length and others with 120 m (Figure 2). Some of them located nearby or extend through water wells or soil test holes. Forward and Reverse seismic shooting were carried out with geophone interval of mostly 10 meters; while few others with 5 meters, using the multi-channel Geod 3000 seismograph with 12 geophones and sledge Hammer source equipment. The accuracy of time measurement is about $10^{-4}$ sec. Plots have been constructed using Seismodule, Pickwin and SeisOpt softwares. Along with the seismic refraction shots that have been carried out in the study area, the actual depth to the water level of the observation wells and other surface water features in the study area has been measured. The recorded levels are used as a geophysical spectrum to test the consistency of the seismic refraction method and its effectiveness for groundwater level detection. While the seismic lines have been completed in most parts which have no water points; the measured water points cover relatively limited parts of the investigated area (Figure 2).

## IV. RESULTS & DISCUSSIONS

The seimogram is the main result of the field work, it represents the analog recording of the received signals. The recorded seismic traces reflect the response of the subsurface interfaces. The most important first arrivals are the direct and refracted waves, which are received by the geophones. Some of the recorded traces have shown certain level of noise and are considered as noisy or bad traces, even after applying the filtering techniques, during the processing stage, in order to enhance the signal/noise ratio. Therefore, some of these bad or highly noisy traces have been eliminated or deleted from some of the shot records. The first arrival picks are taken and tabulated. The time-depth graphs are plotted and the plotted points are best fitted to reflect the layers’ interfaces and the seismic velocities are estimated.

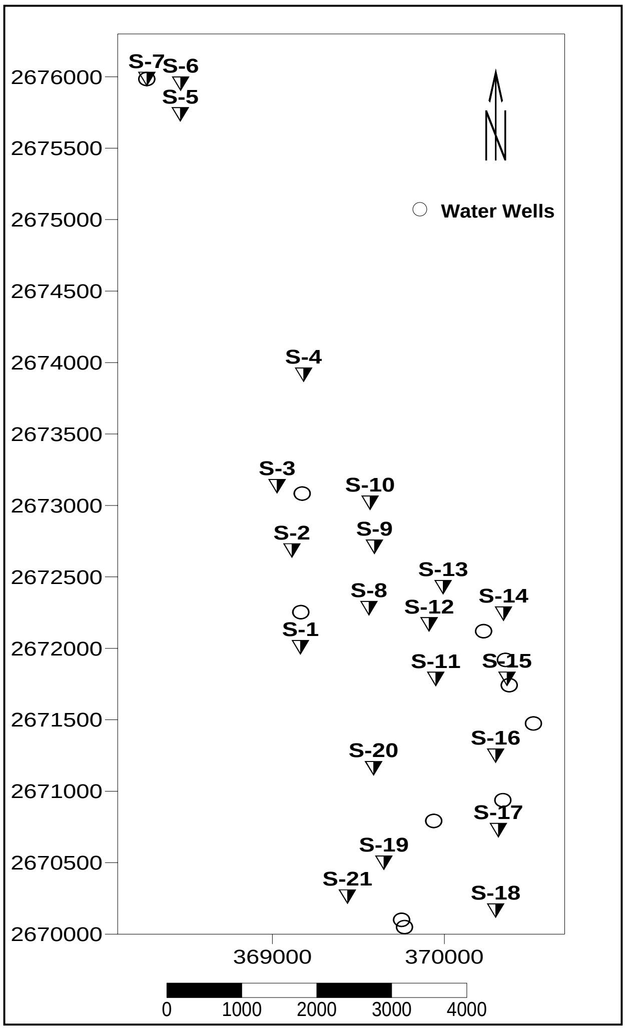



Fig. 2 Location map of the conducted seismic shots and available water wells in the study area

The seismic velocities are calculated from the slope of the fitted lines on the time-distance curve (Appendix 1). Two parameters are usually used to quantify the layer thickness. The first of these is referred to as the cross-over distanc ($X_c$), which simply refers to the offset at which the head wave becomes the first arrival. The second commonly used parameter is called the zero-offset time (intercept time $t_o$). By measuring $x_c$ or $t_o$, in addition to the seismic velocities of the first and second layers, the thickness of the layer (h) can be computed [7].

The elastic properties of the medium will be changed, when the pore volume is filled by water [1]. The groundwater level represents a change in the elastic properties in the "dry" bed above the groundwater contact. The velocity will be characteristic for the grains while in the "wet" bed below the water level, a velocity of about 1430 m/s to 1530 m/s with may be a little bit of change in the water velocity to be 1200 m/s to 1600 m/s is due to the expected conditions and characteristic of water. In case of fine–grained beds for example silt and clays, the adhesive water filling up a great part of the pore volume, gives enough compression elasticity even to a "dry" bed, which reveals itself in the velocity of wave propagation. The practical experiences confirm that the velocity of wave propogation in both dry and wet clays is a value of about 1000 m/s [1]. Thus could expect minor change in groundwater level. If layers of sand underlay the groundwater level are interbeded with clay, the waves refracted from the water level and the boundary between sand and clay beds may interfere with one another. In case of clay interbedding occurs in the dry sand beds overlying the groundwter table, waves refracted from the sand-clay boundary may completely screen refraction arrivals from the groundwater level. Time-distance curves of selected shot records are shown in Appendix 1.

Practically, the obtained results from all shot records and interpretation indicate that the minimum seismic velocity range of 251-1080 m/s was observed in the unsaturated weathered material above the water level (e.g. as observed from the Time-Distance curve at shots 22 & 21). The saturation zone has a velocity in range of 1490-1600 m/s (e.g. as observed from the Time-Distance curve at shots 13 & 14) or a slighly higher, while in the underlying weathering rocks the range is from 1700 to 3860 m/s (e.g. as observed from the Time-Distance curve at shots 6 & 24 respectively). This velocity range may represent the beds' interfaces. Refracting velocity at water level will be lowest when the water level is at the shallowest depth. The water level drops closer to the top of the permanently saturated zone, refracting velocities are observed to increase and only the permanent water level can be seen with refraction methd. The distriubtion of the seismic refracting velocity of the water level in the study area is seen in Figure 3.

The geomorphologic evaluation of the study area indicates that it is almost flat and has no any drainage pattern systems except from the eastern border. However the western limbs of the anticline fold of Hafit structure contains some drainage pattern. This pattern includes small tributaries that connect to each other and finally form major valleys [8]. These valleys drain its water during any seasonal rainfall toward the investigated area which may cause some hazards. Therefore, it can be foreseen that longitudinal trench perpendicular to the present drainage system should be excavated in order to avoid any future damages on the residential villas.

The recorded depths to water level values indicate that the minimum value is 2.3 m the maximum value is 16 m and the average equals to 11 m. The high variation in water level depth within this narrow pilot area refers to the complicated groundwater regime which might be of a great heterogeneity in the water bearing formations as well as the sources of water supply. The occurrence of big thickness of evaporites, marl and muddy limestone of lateral and vertical variation lead to present high water level differences. The upper Quaternary deposits which represent the upper most zones of the groundwater aquifers in the area may also contain digenetic features that gave rise to the existence of some perched water zones within the study area, which is responsible for the shallower water depths from the ground surface. The lithological constituents of two available and relatively nearby drilled groundwater wells in the area, which contain gravel, fossiliferous limestone, clay and mudstone, contribute to the interpretation. The average readings reflect the general groundwater water level depth within the main aquifer at the western side of Jabal Hafit in Al- Ain city. The maximum values of water level depth (21.6 and 19.25 m) could be ascribed to improper groundwater well design and development.

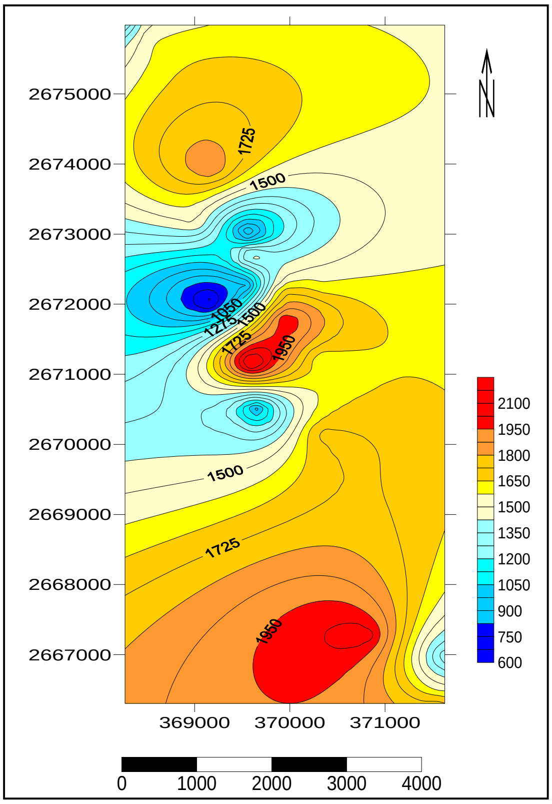



Fig. 3 Seismic refracting velocity of water level contour map

A pumping test has been performed using one of the available groundwater wells in order to study the water level fluctuation and its relationship to the hydrologic properties of the groundwater aquifer within the studied pilot area. The well is of 10 inch diameter with approximately 100 feet depth. The working pump is of 5 $m^3$/h and 2 inch riser pipes diameter. The discharging amount of groundwater is withdrawn directly to a ground reservoir. The analyses of the pumping test data reveal that the transmissivity of the tested aquifer is 100 $m^3$/d and the hydraulic conductivity is 5 meter/day (Figure 4), which confirm the poor properties of the occurred groundwater aquifer in the study area. In the other words, if there is any recharge for the aquifer from any surface water features such as seasonal rainfall or infiltration water from the adjacent farms, this will cause rising of groundwater level with time**.** This upward increment in water level can greatly affect the foundations of the present residential villas.

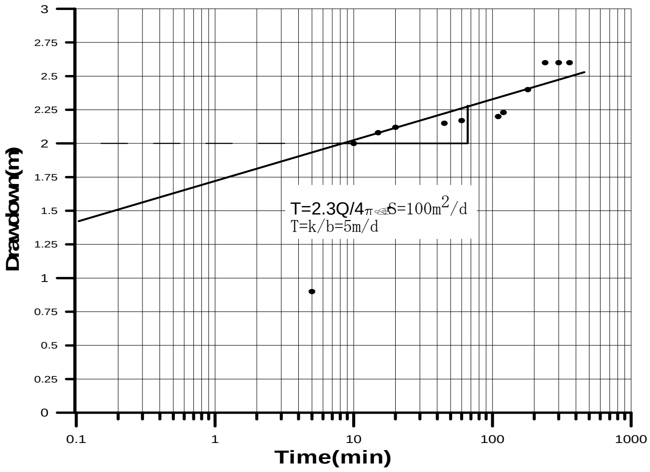



Fig. 4 Time-drawdown plot for pumping test in the study area according to [9]

The results of the seismic refraction shot records analyses are integrated with the available measurements of water level to produce a combined water level of the area. The obtained water level depths of the available water points in the study area are represented in three contour maps. The first and second maps are the recorded water level, while the third is combined with the results of the seismic shots results (Figures 5, 6 and 7). The distribution of water level values in the study area reflects the increment of water level depth toward the south-south west (Figure 5). This is due to the increasing of the ground elevation in the direction of Jabal Hafit heights.

The contouring of the obtained seismic refraction values (Figure 6) indicates a consistency of the contoured map of the groundwater wells data, except for features of decreasing in the water level which may be attributed to the existence of non-homogeneous lithological constituents. These features could be explained as perched water level rather than accurate groundwater level depths within the study area. The present shallow water features along the study area, such as dug wells and surface water cement Factory Lake as well as the water seepage from Mubazarah surface water contribute to this interpretation.

The combined contour map of seismic and groundwater level shows a reasonable image of the depth to groundwater level distribution within the study area (Figure 7). The shallower water depths may refer to the uplift of the water level which may be due to incapability of the aquifer to receive any additional water quantity from any surface recharge sources.

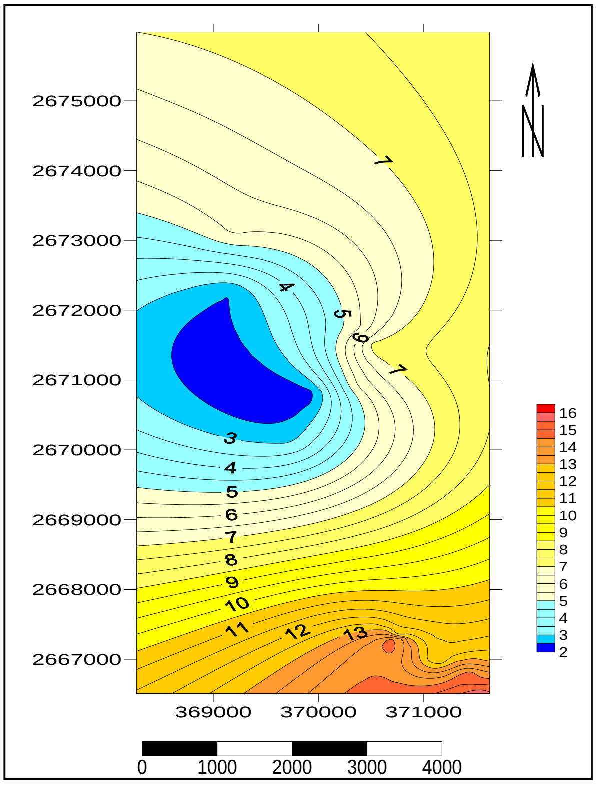



Fig. 5 Depth to water level contour map from available wells in the study area

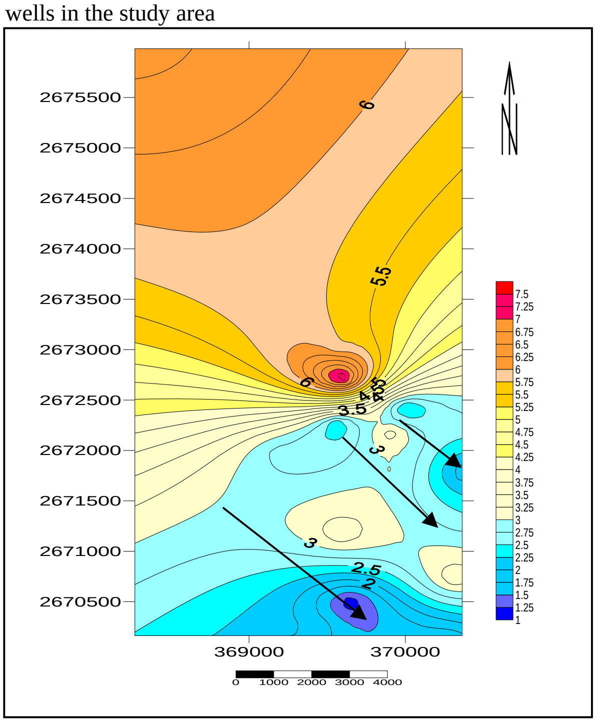



Fig. 6 Depth to water level contour map from seismic shots

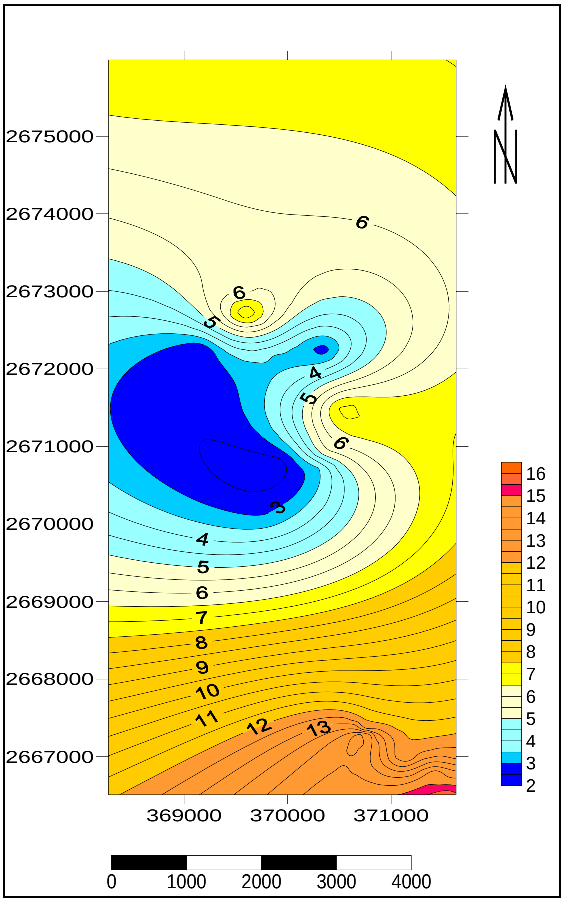



Fig. 7 Combined contour of the depth to water level results from measured field data and seismic refraction shots.

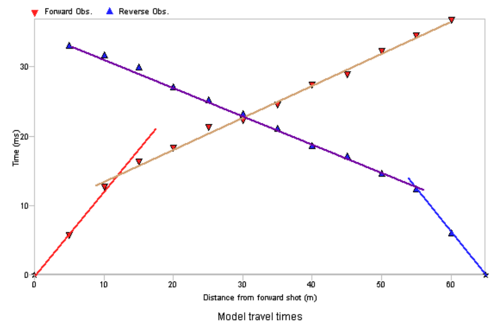
## V. Conclusion

Seismic refraction has been used to investigate the level of the groundwater in a pilot area nearby Jabal Hafit in Al-Ain city of the UAE. The obtained measurements in the saturated zone indicates seismic velocities ranges between 1430-1600 m/s, while at the top of the capillary fringe zone give rise to another response indicated by seismic velocity range between 251-1080 m/s. The resulted water level maps show general agreement and similarity between the measured wells map and the seismic refraction water level map. Some shallow depths are indicated which may reflect the surface of perched water zone. The processed seismic data in integration with the water level measurements suggest that the deepest and shallowest groundwater levels are 16 and 2.3 meters respectively. The maximum values indicate the accurate groundwater level within the study area. These findings can be considered as preliminary data to help the decision makers. This study recommended that the monitoring of water level in the study area should be done periodically to protect the residential areas from any sudden rise in water level. Also, the expected damage due to sudden water storms should be avoided through implementation of surface engineering protection from the eastern side of the study area. This is due to the existence of the western limb of Jabal Hafit anticlinal fold.

## Appendix 1

### Time Distance Curve for All Shots

### Shot 1

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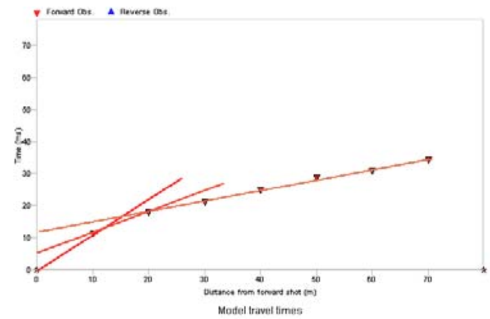
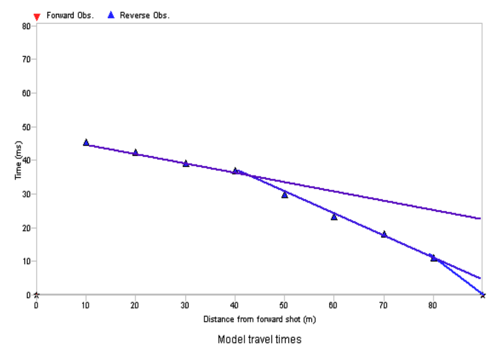



### SHOT 6

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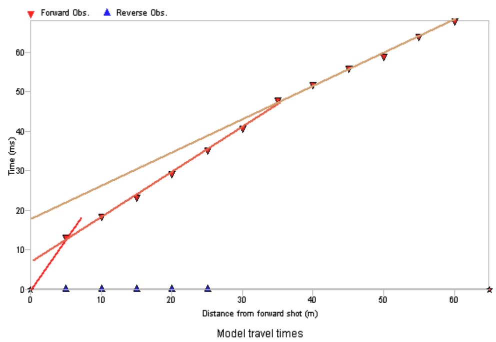

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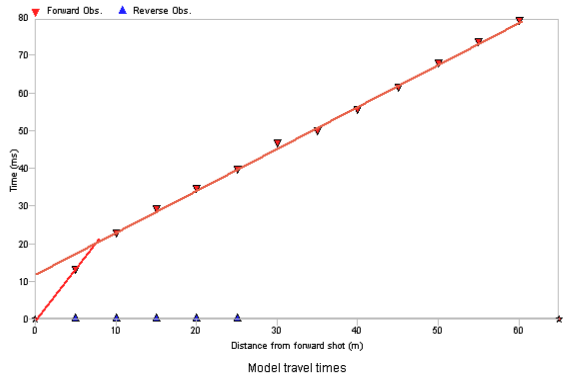


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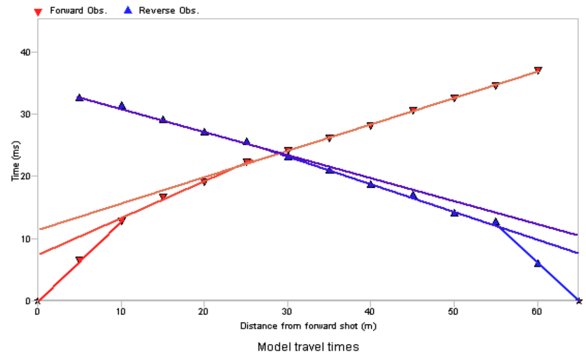


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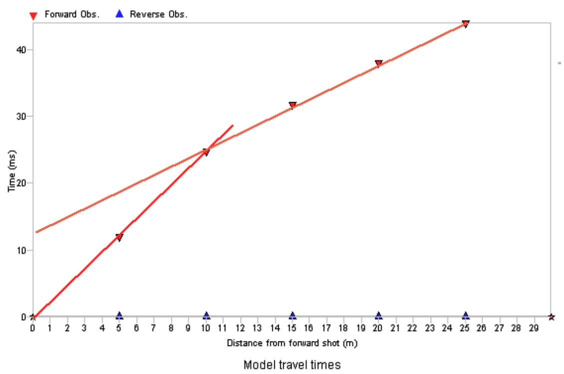


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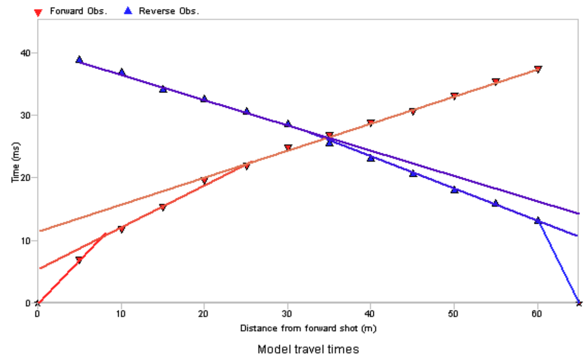


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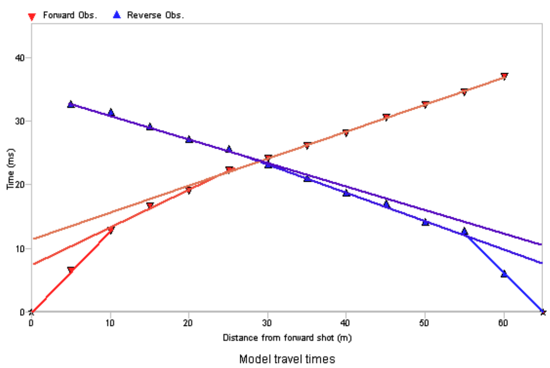


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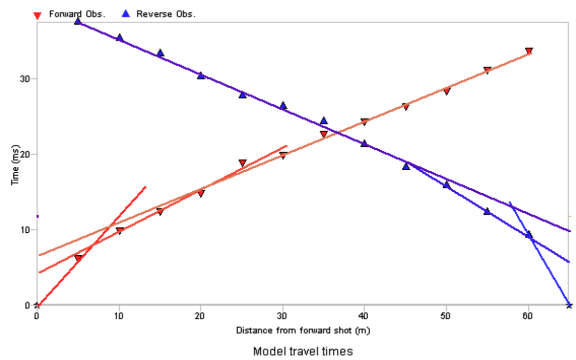


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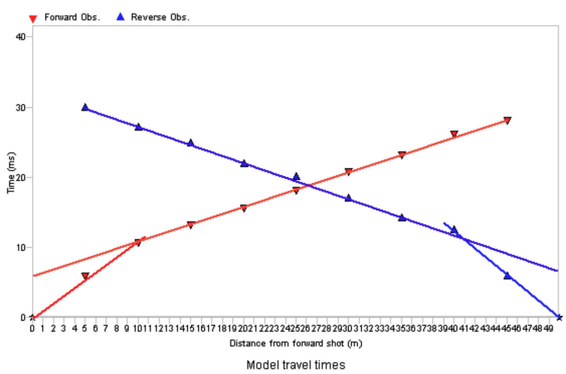


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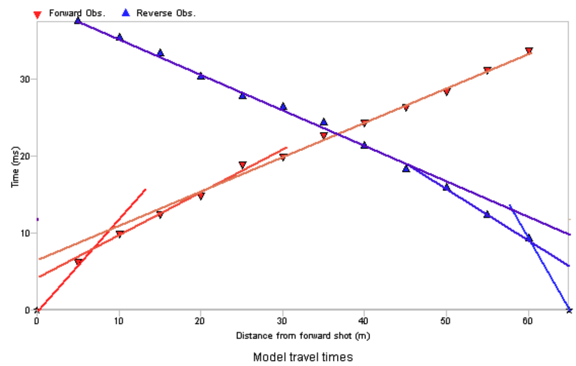

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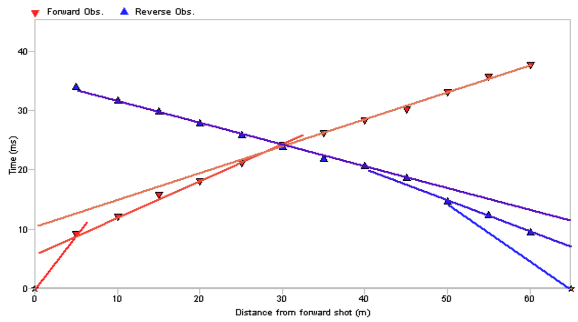
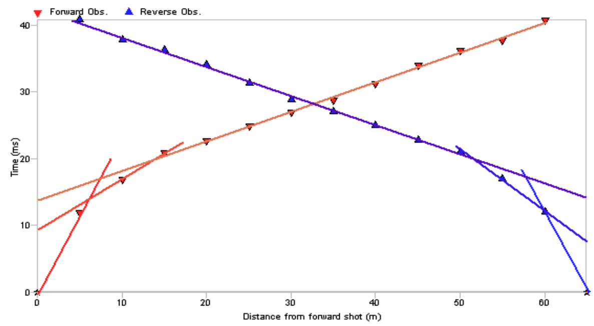



Model travel times

SHOT 20

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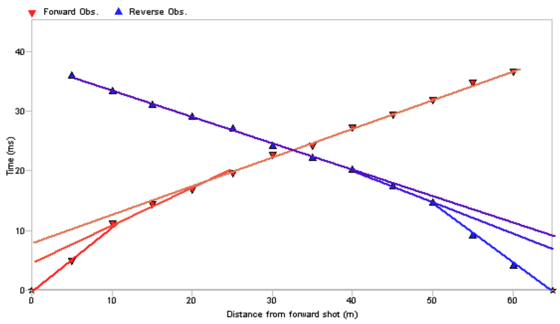
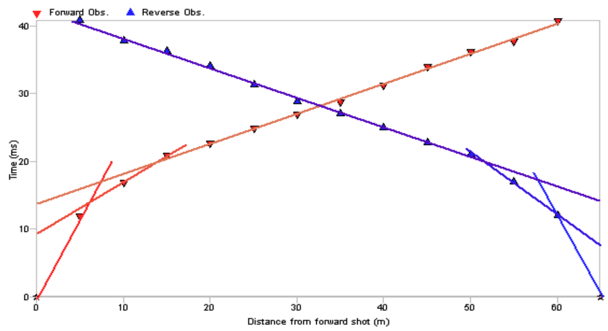


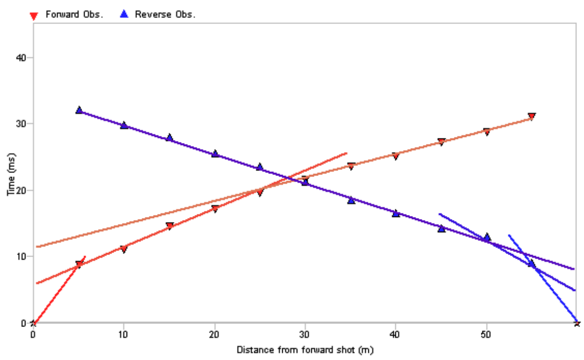

Model travel times

SHOT 21



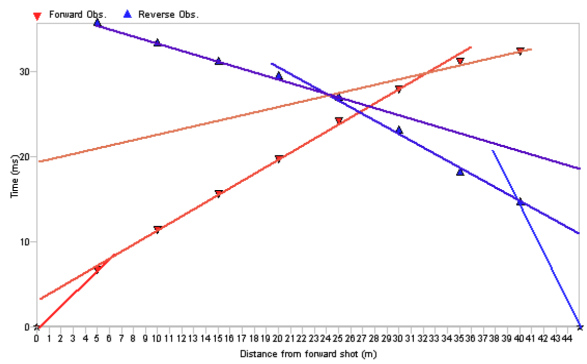

Model travel times

SHOT 18



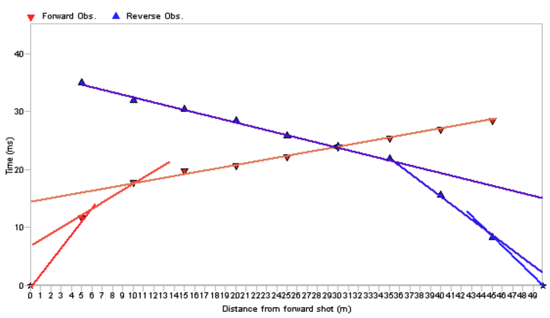

Model travel times

SHOT 22



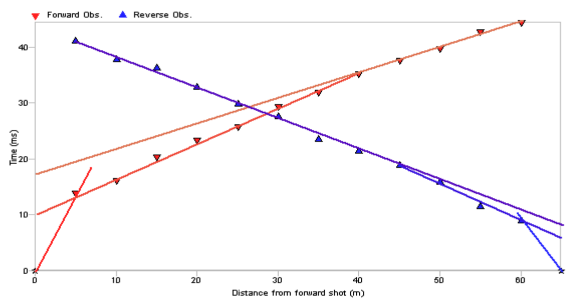

Model travel times

SHOT 19



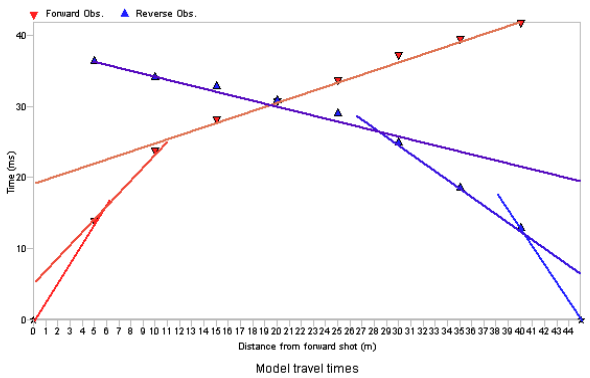

Model travel times

SHOT 23




Model travel times

SHOT 24

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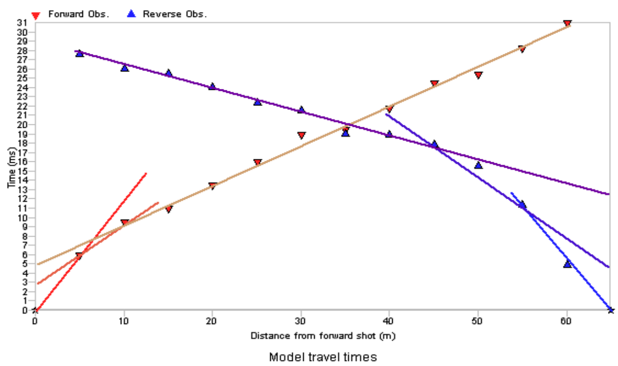


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