INVESTIGATING ANISOTROPY AND INHOMOGENEITY USING TOMOGRAPHIC INVERSION OF VSP TRAVELTIMES: VALIDATION OF ANALYTIC EXPRESSIONS FOR LINEARLY INHOMOGENEOUS ELLIPTICALLY ANISOTROPIC MODELS

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Investigating anisotropy and inhomogeneity using tomographic inversion of VSP traveltimes: Validation of analytic expressions for linearly inhomogeneous elliptically anisotropic models

by

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ABSTRACT

Tomographic inversions of zero-offset and walkaway VSP data were performed using an analytical traveltime expression for a linearly inhomogeneous elliptically anisotropic model. Both isotropic and anisotropic conditions were investigated by forward and inverse modelling. It was realized that to accommodate long offsets, i.e., beyond the turning-ray offset, the analytic equation for traveltime needed to be reformulated so that only single-valued functions were obtained with offset.

A practical aspect of determining the elliptical anisotropy parameter, χ, is in applying it in the expression for the curve that distinguishes between the downgoing and upgoing arrivals or 'turning points'. This has importance in the planning and designing of surveys, in that appropriate depths for receiver and source placements can be predetermined, with a reasonable estimation of inhomogeneity and anisotropy, to avoid acquiring data that would not be useful.

Extensively applying the algorithm to a large volume of real and synthetic data is an indication of the robustness of the methodology.

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LIST OF SYMBOLS AND ACRONYMS

a	vertical velocity at zero depth
b	gradient (rate of increase in vertical velocity with depth)
χ	ellipticity parameter
p	ray parameter
θ	ray angle
v	velocity
v_{H}	horizontal velocity
v_{V}	vertical velocity
V_x	magnitude of horizontal ray velocity
V_z	magnitude of vertical ray velocity
z	depth
AVO	amplitude versus offset
MSL	mean sea level
3C	three-component
VD	vertical depth
VSP	vertical seismic profiling
VTI	vertical transverse isotropy
WAVSP	walkaround VSP
WVSP	walkaway VSP
ZVSP	zero-offset VSP

CHAPTER 1: INTRODUCTION AND OVERVIEW

1.1 INTRODUCTION

Vertical seismic profiling (VSP) is a technique for obtaining measurements in the vicinity of a borehole by placing one or more receivers in the borehole with sources at the surface or *vice versa*. An analytical expression and algorithm was developed by Slawinski et al. (2004) using tomographic inversion of VSP traveltimes to determine the anisotropy in transversely isotropic media with a vertical axis of symmetry (VTI) by a velocity model described by three parameters a, b and χ, with the assumptions that

i) velocity (v) increases linearly with depth, i.e., $v = a + bz$,

with a being the velocity at zero depth, b being the gradient which defines the rate of increase in velocity with depth, z, and

ii) anisotropy results from an elliptical velocity dependence on direction, defined by the ellipticity parameter, χ, given by:

$$\chi := \frac{v_{\mathrm{H}}^2 - v_{\mathrm{V}}^2}{2v_{\mathrm{V}}^2}, \tag{1.1}$$

which is a constant for all z, with v_{H} and v_{V} being the horizontal and vertical wavefront velocities, at any depth, respectively.

The following analytical expression and subsequent algorithm for traveltime as described by Slawinski et al. (2004) was tested with acquired walkaway VSP data and found to be suitable for offset distances up to the 'turning point' of the ray:

$$t = \frac{1}{b}\ln\left[\frac{a+bz}{a}\frac{1+\sqrt{1-p^2a^2(1+2\chi)}}{1+\sqrt{1-p^2(a+bz)^2(1+2\chi)}}\right], \tag{1.2}$$

where p is the ray parameter, and χ is the ellipticity parameter defined above.

As a result of the findings that expression (1.2) was not applicable to offsets beyond the turning points of rays it was modified by Slawinski (pers. comm.) to take into account longer offsets:

$$t = \frac{1}{2b}\left[\ln\frac{1-\sqrt{1-p^2a^2(1+2\chi)}+pbX}{1+\sqrt{1-p^2a^2(1+2\chi)}-pbX} - \ln\frac{1-\sqrt{1-p^2a^2(1+2\chi)}}{1+\sqrt{1-p^2a^2(1+2\chi)}}\right], \tag{1.3}$$

where a, b, χ are as described above, p is the ray parameter, X is the offset.

To obtain expression (1.3), integration is performed along the offset (x)-axis giving a single-valued function of traveltime for the ray, whereas expressing the ray by integration along the depth (z)-axis in obtaining expression (1.2) gave a nonsingle-valued function due to the same traveltime for downgoing and upgoing signals at the same depth.

Vertical seismic profiling (VSP) data acquired offshore Newfoundland are used for the determination of a, b and χ, and to show the fit to both the original traveltime expression (1.2) and the reformulated expression (1.3).

A brief description on the theoretical basis of the traveltime equations is included. Synthetic data sets generated to confirm the algorithm as well as to help with the understanding of the results obtained with the real-data set used are also discussed. Our main focus, however, is on the results obtained using the real data. We show the fit of real data to the original equation on which the algorithm is based for the determination of anisotropy parameters, the justification to change the equation to accommodate longer offsets and the results of comparing forward modelling to the real data using both the original and newly derived equations. We also show the expression for the curve that distinguishes between the downgoing and upgoing arrivals or 'turning points'. This has importance in the planning and designing of surveys, since with a reasonable guess of a, b and χ one can determine the appropriate depths for receiver and source placements and avoid acquiring data that would not be useful.

This thesis complements the M.Sc. thesis of Chad J. Wheaton (2004) supervised by Dr. Michael A. Slawinski, entitled: Tomographic traveltime inversion for linear inhomogeneity and elliptical anisotropy, which showed the derivation of the original traveltime expression.

1.2 OBJECTIVES

The objective of the thesis is to assess the fit of real data to an analytically derived traveltime expression for a linearly inhomogeneous elliptical anisotropic model, thereby

i) validating the methodology and algorithm used,

ii) confirming the assumptions of linear inhomogeneity and elliptical anisotropy, and

iii) showing the contribution of anisotropy in modelling the real earth.

1.3 OVERVIEW OF THEORY

1.3.1 Traveltime Integral

The total traveltime along a ray, for a given source receiver pair can be written in integral form as:

$$t = \int \frac{\mathrm{d}s}{V}, \tag{1.4}$$

where d*s* is the arclength element along the ray, and *V* is the velocity of propagation along this element, as shown in Figure 1.1.

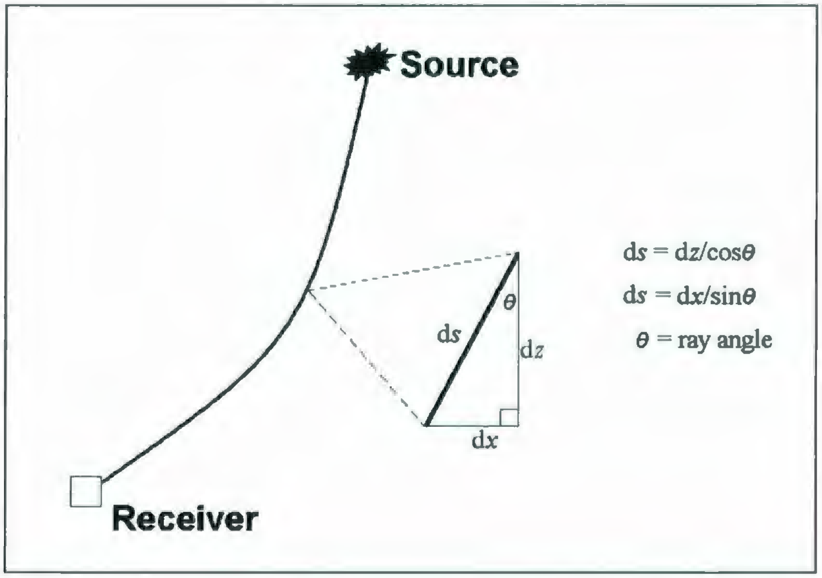


Figure 1.1: Arclength of an element, d*s*, along a ray. The traveltime integral between source and receiver is obtained by integration along the *x*-axis, as shown in expression (1.5).

In the xz-plane, the arclength element, ds, is given by $ds = dx/\sin\theta$ or as $ds = dz/\cos\theta$, where θ is the ray angle. To get the traveltime integral between source at (0, 0) and receiver at (X, Z), we integrate along the x-axis (along the x-axis a ray is expressed as a single-valued function, whereas this is not the case along the z-axis due to downgoing and upgoing rays):

$$t = \int_{o}^{X} \frac{dx}{V(\theta, z)\sin\theta}, \tag{1.5}$$

To integrate, we need to know the expression for $V(\theta, z)$ and $\sin\theta$ in terms of constants a, b, χ, p, and the integration variable x.

We consider the source at (0, 0) and receiver at (X, Z) in derivations and discussions for convenience. However, the two are interchangeable, i.e., the source can be at (X, Z) and receiver at (0, 0).

1.3.2 Ellipticity Parameter, χ

Assuming that the ray velocity varies along the z-axis in such a way that the ratio of magnitudes of horizontal and vertical ray velocities, χ, remains constant, $V(\theta, z)$ is given by Slawinski (2007):

$$V(\theta,z)=V_z(z)\sqrt{\frac{1+2\chi}{1+2\chi\cos^2\theta}}. \tag{1.6}$$

Parameter χ is the measure of the ellipticity, given by

$$\chi:=\frac{V_x^2-V_z^2}{2V_z^2}, \tag{1.7}$$

where V_x and V_z are the magnitudes of the horizontal and the vertical ray velocities, respectively. Since the x-axis and z-axis are the symmetry axes for an ellipse, the ray velocities are equal to wavefront velocities used in expression (1.1).

1.3.3 Direct Traveltime Expression

If we assume further that the magnitude of the ray velocity increases linearly along the z-axis, we can write expression (1.6) as

$$V(\theta,z)=(a+bz)\sqrt{\frac{1+2\chi}{1+2\chi\cos^2\theta}}, \tag{1.8}$$

where a and b are positive constants.

Provided the ray velocity varies in the z-direction, and not in the x-direction, the ray parameter, p, along a given ray, $z\,(x)$, which is a conserved quantity, is given by Slawinski and Webster (1999):

$$p = \cos\theta \frac{\partial}{\partial\theta}\left[\frac{1}{V(\theta,z)}\right] + \frac{\sin\theta}{V(\theta,z)}. \tag{1.9}$$

Substituting for $V\,(\theta,\, z)$, we obtain:

$$p = \cos\theta \frac{\partial}{\partial\theta}\left[\frac{1}{(a+bz)\sqrt{\dfrac{1+2\chi}{1+2\chi\cos^2\theta}}}\right] + \frac{\sin\theta}{(a+bz)\sqrt{\dfrac{1+2\chi}{1+2\chi\cos^2\theta}}} \tag{1.10}$$

$$= \frac{1}{(a+bz)\sqrt{1+2\chi}}\left(\cos\theta\frac{\partial}{\partial\theta}\sqrt{1+2\chi\cos^2\theta} + \sin\theta\sqrt{1+2\chi\cos^2\theta}\right) \tag{1.11}$$

$$= \frac{\sin\theta}{(a+bz)\sqrt{1+2\chi}\sqrt{1+2\chi\cos^2\theta}}. \tag{1.12}$$

So,

$$\sin\theta = p(a+bz)\sqrt{1+2\chi}\sqrt{1+2\chi\cos^2\theta}\ . \tag{1.13}$$

And,

$$V(\theta,z)\sin\theta = (a+bz)\sqrt{\frac{1+2\chi}{1+2\chi\cos^2\theta}}p\ (a+bz)\sqrt{1+2\chi}\sqrt{1+2\chi\cos^2\theta} \tag{1.14}$$

$$= p\ (a+bz)^2(1+2\chi)\,. \tag{1.15}$$

To proceed with integration, we must express z in terms of x.

From expression (1.13),

$$p = \frac{\sin\theta}{(a+bz)\sqrt{1+2\chi}\sqrt{1+2\chi\cos^2\theta}}\,. \tag{1.16}$$

To obtain the ray parameter, p, in terms of position variables x and z, we divide both the numerator and the denominator by sin θ, to get

$$p = \frac{1}{(a+bz)\sqrt{1+2\chi}\sqrt{1+\frac{2\chi+1}{\tan^2\theta}}}\,. \tag{1.17}$$

Squaring both sides and rearranging, we get

$$\frac{1}{\tan^2\theta} = \frac{1-p^2(a+bz)^2(1+2\chi)}{p^2(a+bz)^2(1+2\chi)^2}. \qquad (1.18)$$

Now, $1/\tan^2\theta = (\mathrm{d}z/\mathrm{d}x)^2$, so the above equation can be rewritten in terms of position variables, x and z, as

$$\frac{\mathrm{d}z}{\mathrm{d}x} = \frac{\sqrt{1-p^2(a+bz)^2(1+2\chi)}}{p\ (a+bz)\ (1+2\chi)}, \qquad (1.19)$$

and subsequently,

$$\mathrm{d}x = \frac{p\ (a+bz)\ (1+2\chi)}{\sqrt{1-p^2(a+bz)^2(1+2\chi)}}\mathrm{d}z. \qquad (1.20)$$

If we consider the source to be located at the origin, we can set the initial conditions as $z\,(0) = 0$, and integrate as follows:

$$\int_o^x \mathrm{d}\varepsilon = \int_o^z \frac{p\ (a+b\varsigma)(1+2\chi)}{\sqrt{1-p^2(a+b\varsigma)^2\ (1+2\chi)}}\mathrm{d}\varsigma, \qquad (1.21)$$

where ξ and ς are the integration variables, to obtain

$$x = \frac{1}{pb}\left[\sqrt{1 - p^2a^2(1+2\chi)} - \sqrt{1 - p^2(a+bz)^2(1+2\chi)}\right], \tag{1.22}$$

which describes the ray given by x (z) for elliptical velocity dependence with direction and a linear velocity dependence with depth.

We can write expression (1.22) as

$$\left(pbx - \sqrt{1 - p^2a^2(1+2\chi)}\right)^2 = 1 - p^2(a+bz)^2(1+2\chi). \tag{1.23}$$

Recalling from expressions (1.14) and (1.15) that

$$V(\theta,z)\sin\theta = p\ (a+bz)^2(1+2\chi), \tag{1.24}$$

and substituting, we get

$$\left(pbx - \sqrt{1 - p^2a^2(1+2\chi)}^{\,2}\right) = 1 - pV(\theta,z)\sin\theta. \tag{1.25}$$

Solving for $V \sin\theta$, we get

$$V(\theta,z)\sin\theta = \frac{1 - \left(pbx - \sqrt{1 - p^2a^2(1+2\chi)}\right)^2}{p}, \tag{1.26}$$

which is the denominator in the integral expressed in terms of variable x, expression (1.5). Inserting expression (1.26) into expression (1.5) and using the fact that p is constant for a given source-receiver pair, we can write

$$t = p\int_{o}^{X} \frac{\mathrm{d}x}{1-\left(pbx-\sqrt{1-p^2a^2(1+2\chi)}\right)^2}. \tag{1.27}$$

By substituting

$$\varsigma := pbx-\sqrt{1-p^2a^2(1+2\chi)}\ , \tag{1.28}$$

we can rewrite the above equation as:

$$t = \frac{1}{b}\int_{-\sqrt{1-p^2a^2(1+2\chi)}}^{pbx-\sqrt{1-p^2a^2(1+2\chi)}} \frac{\mathrm{d}\varepsilon}{1-\varsigma^2}. \tag{1.29}$$

Using partial fractions, we get

$$t = \frac{1}{2b}\int_{-\sqrt{1-p^2a^2(1+2\chi)}}^{pbx-\sqrt{1-p^2a^2(1+2\chi)}} \left(\frac{1}{1-\varsigma}+\frac{1}{1+\varsigma}\right)\mathrm{d}\varsigma. \tag{1.30}$$

Integrating, we get

$$t = \frac{1}{2b} \ln \frac{1+\varsigma}{1-\varsigma} \Bigg|_{-\sqrt{1-p^2a^2(1+2\chi)}}^{pbx-\sqrt{1-p^2a^2(1+2\chi)}} . \tag{1.31}$$

Evaluating, we obtain

$$t = \frac{1}{2b}\left[\ln \frac{1-\sqrt{1-p^2a^2(1+2\chi)}+pbX}{1+\sqrt{1-p^2a^2(1+2\chi)}-pbX} - \ln \frac{1-\sqrt{1-p^2a^2(1+2\chi)}}{1+\sqrt{1-p^2a^2(1+2\chi)}} \right], \tag{1.32}$$

which is equation (1.3).

Using the identity for hyperbolic functions

$$\tanh^{-1}\varsigma = \frac{1}{2} \ln \frac{1+\varsigma}{1-\varsigma}, \tag{1.33}$$

we can write

$$t = \frac{\tanh^{-1}\left[pbX - \sqrt{1-p^2a^2(1+2\chi)} \right] + \tanh^{-1}\sqrt{1-p^2a^2(1+2\chi)}}{b}. \tag{1.34}$$

Expression (1.34) is equivalent to expression (1.3). It allows us to obtain the traveltime for a signal between a given source-receiver pair along an elliptical arc using the property that the ray parameter, *p,* is constant and unique for a particular ray in a laterally homogeneous continuum.

1.3.4 Ray Parameter, *p*

To find the expression for p that corresponds to the source at $(X, 0)$ and the receiver at $(0, Z)$, we use the fact that p is a constant since, for a given source receiver pair in a laterally homogeneous continuum, p is a conserved quantity along the ray. Recalling expression (1.22) ,

$$x = \frac{1}{pb}\left[\sqrt{1-p^2a^2(1+2\chi)} - \sqrt{1-p^2(a+bz)^2(1+2\chi)}\right],$$

we can write, (Slawinski, 2009):

$$X = \frac{1}{pb}\left[\sqrt{1-p^2a^2(1+2\chi)} - \sqrt{1-p^2(a+bZ)^2(1+2\chi)}\right]. \tag{1.35}$$

Solving for p, we obtain

$$p = \frac{2X}{\sqrt{\left[X^2 + (1+2\chi)Z^2\right]\left[(2a+bZ)^2(1+2\chi) + b^2X^2\right]}}. \tag{1.36}$$

Using expression (1.36) we can obtain p, which is constant and unique for a particular choice of source-receiver pair. We can then use expression (1.34) to obtain the traveltime for a signal between the source and receiver.

1.3.5 Elliptical Rays - Downgoing and Upgoing Signals (Turning Points)

For traveltime measurements, the receiver in the borehole can be reached by a downgoing or an upgoing signal travelling along an elliptical arc.

If the source is directly above a given receiver, the takeoff ray angle for the downgoing signal is $\theta = 0$. As the source offset X increases, so does θ, until the takeoff ray angle corresponds to the ray that horizontally impinges the receiver from the source at (X, Z); the takeoff angle is at its maximum. From that point on, the ray takeoff angle begins to decrease, and the receiver is reached by the upgoing signal travelling along an elliptical arc. For a source at an infinite horizontal distance, the receiver would be reached by a ray whose takeoff angle is nearly zero - the ray is nearly vertical at takeoff. Figure 1.2 illustrates the rays for a receiver at a depth of 2000 m. The 'impinging ray' (thick curve) has a source offset of approximately 4000 m. To the left of this curve signals at the receiver arrive from above and are downgoing. To the right of this curve signals arrive from below the receiver and are upgoing.

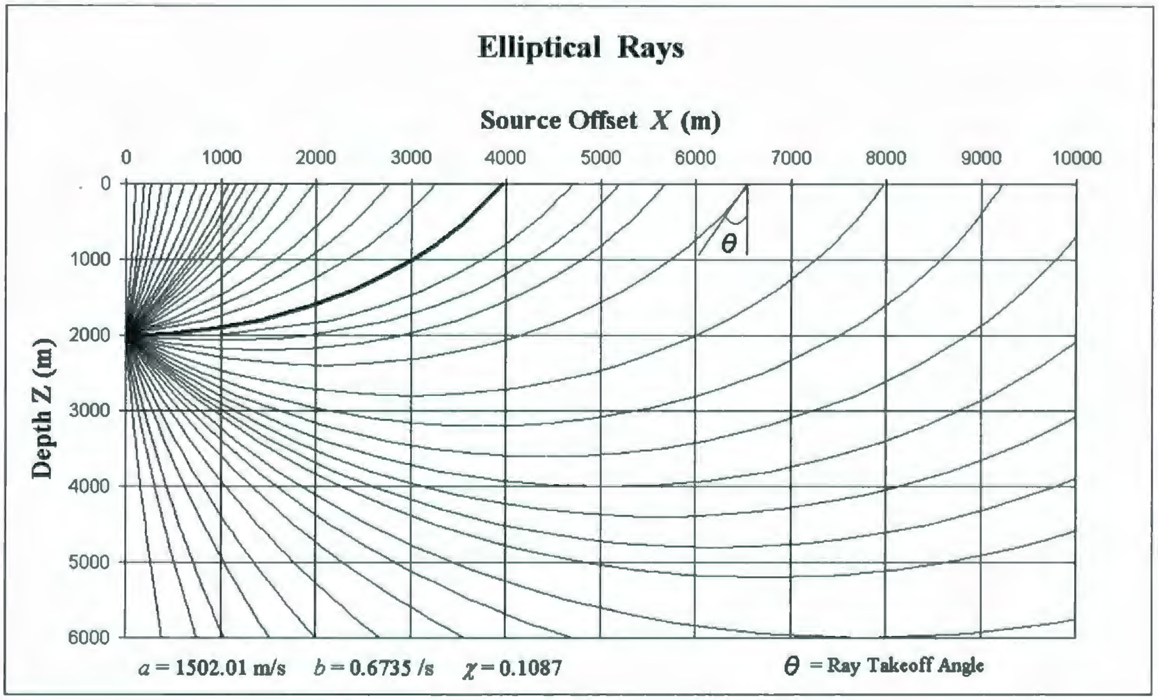


Figure 1.2: The thick curve shows the ray that horizontally impinges the receiver at (0, 2000) with the source at (4000, 0) and where θ, the ray takeoff angle is at its maximum. For sources placed to the left of this curve, signals at the receiver arrive from above and are downgoing. $\theta = 0$ when the source is directly above the receiver. For sources placed to the right of this curve, signals at the receiver arrive from below the receiver and are upgoing.

To find point x at depth Z at which the ray angle reaches its largest value, which is the so-called turning point, we write expression (1.36), Slawinski (2009), as

$$p(x;Z) = \frac{2x}{\sqrt{\left[x^2 + (1+2\chi)Z^2\right]\left[(2a+bZ)^2(1+2\chi) + b^2x^2\right]}}, \tag{1.37}$$

and consider its derivative. To find x that corresponds to the maximum of the takeoff angle, we set this derivative to zero and proceed to rearrange the resulting equation using the fact that a, b, χ, and Z are real and a, b, and Z are positive. Thus, we obtain the required solution:

$$x = \sqrt{\frac{1+2\chi}{b}(2a+bZ)Z}\,. \tag{1.38}$$

We can rewrite this solution as

$$\frac{x^2}{\left(\frac{a}{b}\right)^2(1+2\chi)} - \frac{\left(Z+\frac{a}{b}\right)^2}{\left(\frac{a}{b}\right)^2} = 1, \tag{1.39}$$

which is an expression for an hyperbola. To find its asymptote, we set the right-hand side to zero, and solve for x to obtain

$$x = \sqrt{1+2\chi}\left(Z+\frac{a}{b}\right). \tag{1.40}$$

This is the expression for the curve that distinguishes between the downgoing and upgoing arrivals.

The subsurface receiver at $(0, Z)$ is reached by the downgoing signal from the source at $(X, 0)$, if

$$X < \sqrt{\frac{1+2\chi}{b}(2a+bZ)Z} \, . \tag{1.41}$$

For the value of X equal to the right-hand side, the signal is at its deepest point when it reaches the receiver.

CHAPTER 2: DATA ACQUISITION

Data sets from three types of VSPs with different source receiver configurations were utilized: a zero-offset VSP (ZVSP), a walkaround VSP (WAVSP) and a walkaway VSP (WVSP). Each is described below, in the context of how traveltimes are used, and illustrated in Figure 2.1.

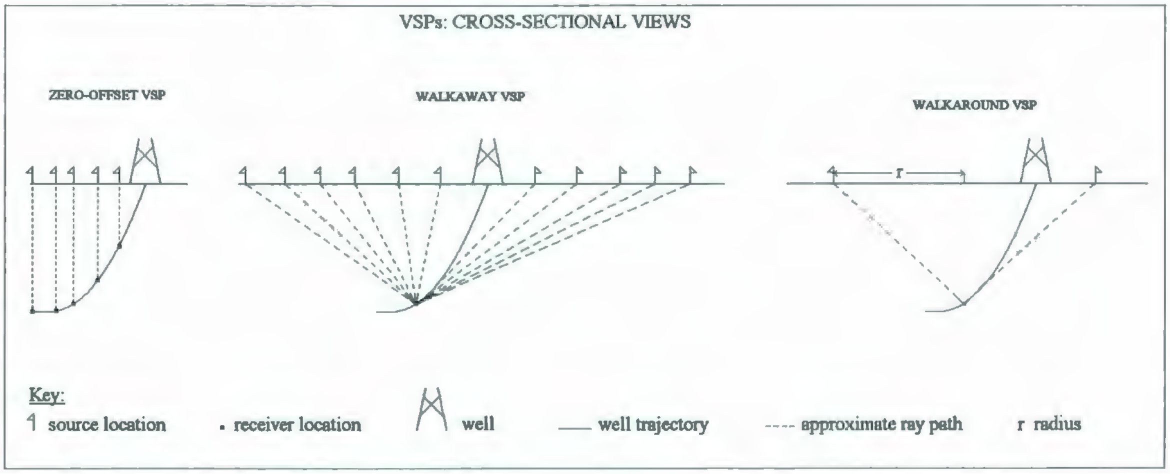


Figure 2.1: Cross-sectional views of the three types of VSPs from which data were acquired. For the zero-offset VSP, sources were placed above the receivers to obtain vertically incident rays. For the walkaway VSP, sources were placed at various offset intervals linearly in a particular direction from the receiver array. In the case of the walkaround VSP, sources were arranged radially around the receiver array.

Zero-offset VSP (ZVSP)

For this type of VSP, for a deviated well, sources are placed at various distances offset from the well and generally vertically above receiver positions in the well. Rays are considered to be vertically incident. Traveltimes observed are used for calibrating sonic logs to seismic times. This type of VSP is also referred to as a walkabove VSP.

Walkaround VSP (WAVSP)

For a walkaround VSP the source is placed at various azimuths in a radial pattern around a receiver position or receiver array. A walkaround VSP provides information on azimuthal variation in traveltimes.

Walkaway VSP (WVSP)

For a walkaway VSP, sources are placed at various offset intervals in a straight line and in specified directions from the receiver position or receiver array. A walkaway VSP is used for imaging a particular horizon, studying amplitude versus offset (AVO) effects, or, as in this case, for the determination of anisotropy from observed traveltimes. It is the key '*in-situ*' field technique available for estimating the anisotropy in a medium.

2.1 WELL CONFIGURATION

VSP data were acquired using the well whose geometry is shown below. Figures 2.2a and 2.2b show a plan view and a cross-sectional view of the well trajectory, respectively. The well was deviated, with a maximum deviation of 52.3°.

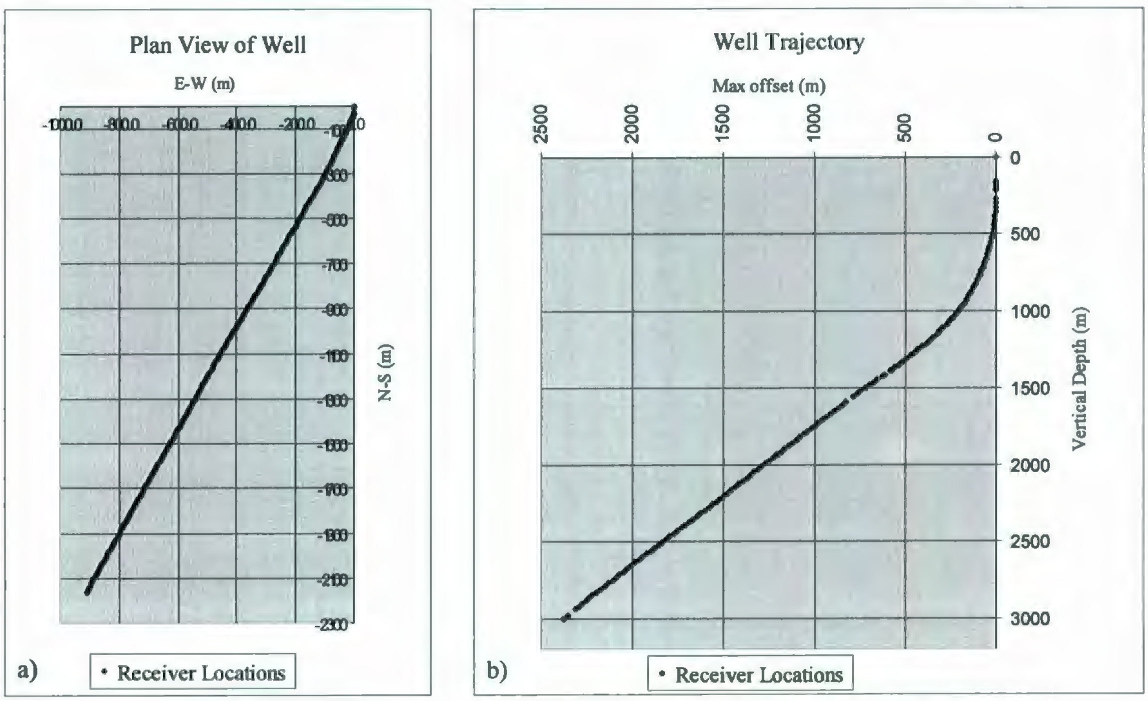


Figure 2.2a): Plan view of well trajectory, referenced to the well location at (0, 0).
b): Well trajectory, with receiver locations for zero-offset VSP. Sources were placed above the receivers to obtain vertical incidence rays.

2.2 EQUIPMENT

2.2.1 Receiver

For the zero-offset and walkaway VSPs, the receivers consisted of packages of three-component geophones configured in a string of five packages (five-level array) with a spacing of 15.0 m between packages. Each package was composed of three orthogonally orientated and gimbal-mounted geophones to enable recording the three orthogonal components of motion.

For the walkaround VSP, the receivers consisted of an eight-level string of three-component geophones, spaced 15.0 m apart. Figure 2.3 depicts the receiver array configurations.

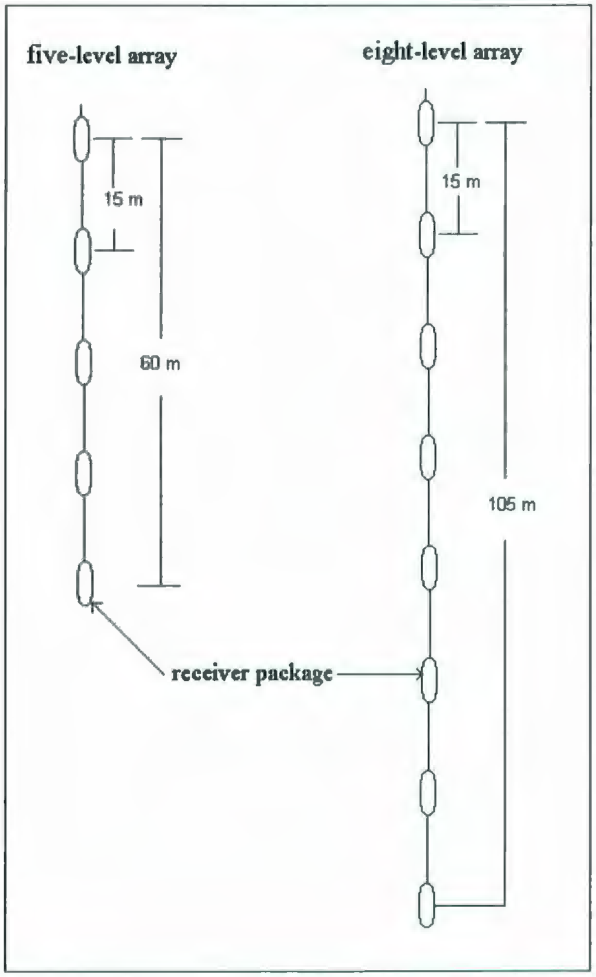


Figure 2.3: Receiver array configurations. The five-level array has a total length of 60 m. The eight-level array has a total length of 105 m. Both arrays consisted of three-component receiver packages sensitive to recording three orthogonal components of motion.

2.2.2 Source

For the zero-offset and walkaway VSPs, the source consisted of a four-gun array, composed of two 100 cc plus two 150 cc air-guns, placed 6.0 m below sea level. A reference hydrophone was positioned 3.5 m above the source array for timing and monitoring purposes.

For the walkaround VSP, the source consisted of an eight-gun array, composed of four 150 cc plus four 300 cc air-guns, placed 6.0 m below sea level. A reference hydrophone was positioned 1.0 m above the source array for timing and monitoring purposes.

2.3 DATA ACQUIRED

Three different types of VSP data sets were acquired in the same well: a zero-offset VSP (or walkabove VSP), a walkaround VSP, and a walkaway VSP.

2.3.1 Zero-offset VSP

For the zero-offset VSP, data were acquired at 15 m intervals from the bottom of the well to the sea floor. This was achieved by pulling the receiver string up the well with source locations being positioned above the center receiver of the five-level array for each position. An average of seven shots were recorded for each depth level. The geophone traces within each level were subsequently aligned and stacked to produce a single trace for each depth level. Figure 2.4 shows the stack response for the z-component geophone.

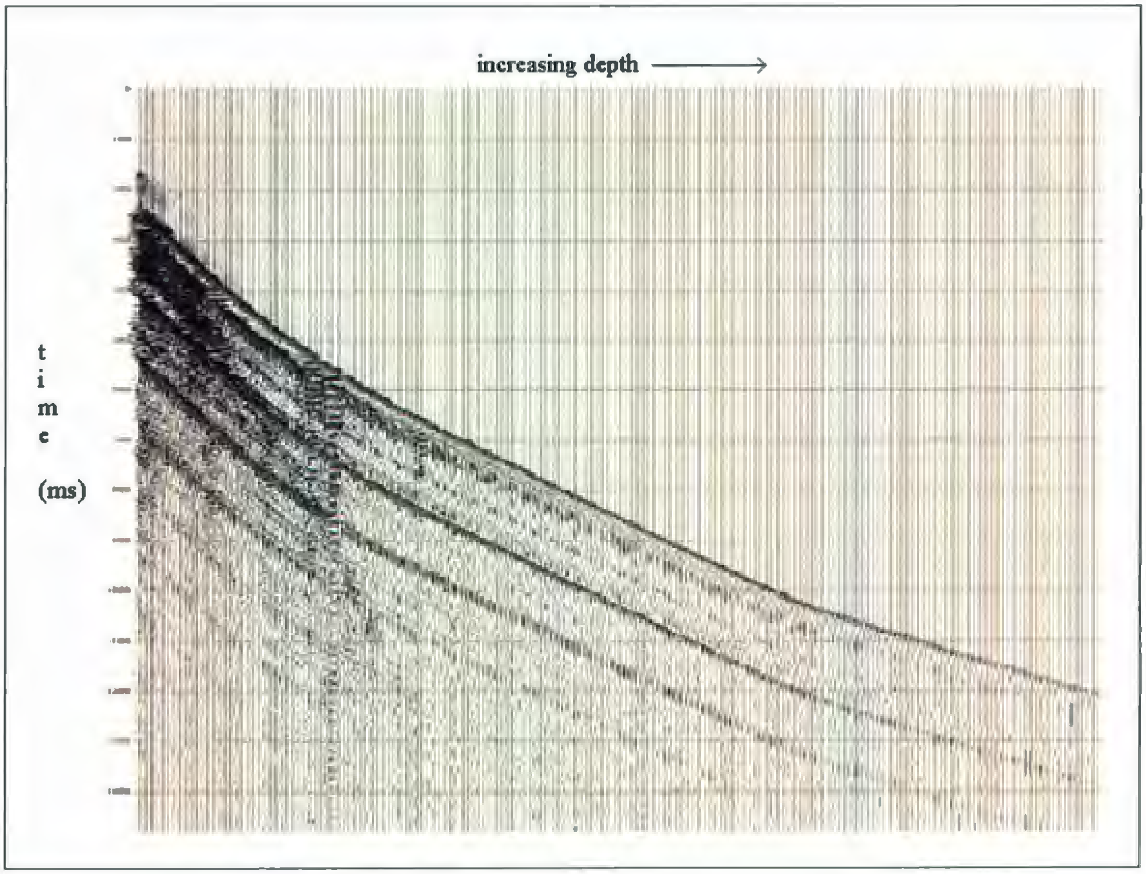


Figure 2.4: Vertical (z-)component stacked data for zero-offset VSP.

2.3.2 Walkaround VSP

Data were acquired in a circular pattern, with a nearly constant radius of 1.5 km, at sea level, as shown in Figure 2.5, for the walkaround VSP. The center of the circle was positioned so as to be above the middle of the central geophone of the eight-geophone array string. Table 2.1 gives the shot and center receiver positions relative to the sea-level position of the well. The geophone string was positioned, at a fixed depth, set to be just above the base of the desired 'effective medium'. A single shot was acquired at source each location. Sixteen shot locations were planned. Fourteen were successfully acquired. The acquisition was aborted due to tool failure and impending severe weather conditions. Figure 2.6 shows the raw geophone traces for each of the shots. The raw data were rotated to obtain the responses in each of the three axes, i.e., vertical z (in the plane of the source-receiver) and horizontal x and y (orthogonal to each other). Figure 3.1 shows the oriented trace responses for each shot.

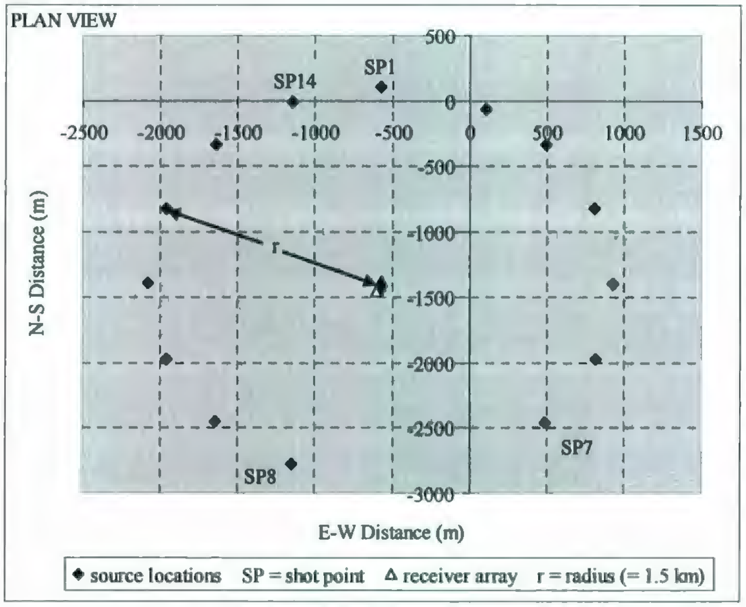


Figure 2.5: Walkaround VSP acquisition geometry. Sources were placed radially around the geophone array at sea level. Distances are as shown in Table 2.1.

Table 2.1: Walkaround VSP acquisition geometry. Sources were placed radially around the geophone array as illustrated in Figure 2.5. Distances are from the sea-level position of the well (0, 0) to each sea-level shot point (SP) position.

SHOT POINT	RECEIVER POSITION		SOURCE POSITION		SOURCE-RECEIVER
	E-W (m)	N-S (m)	E-W (m)	N-S (m)	Radial Distance (m)
SP1	-585.59	-1418.64	-574.84	104.61	1523.29
SP2	-585.59	-1418.64	107.22	-63.39	1522.07
SP3	-585.59	-1418.64	492.22	-333.39	1529.53
SP4	-585.59	-1418.64	810.22	-821.39	1518.22
SP5	-585.59	-1418.64	926.22	-1398.39	1511.95
SP6	-585.59	-1418.64	814.22	-1967.39	1503.53
SP7	-585.59	-1418.64	489.22	-2456.89	1494.38
SP8	-585.59	-1418.64	-1152.78	-2778.39	1473.30
SP9	-585.59	-1418.64	-1644.84	-2450.39	1478.69
SP10	-585.59	-1418.64	-1962.78	-1968.39	1482.86
SP11	-585.59	-1418.64	-2077.78	-1391.89	1492.43
SP12	-585.59	-1418.64	-1960.84	-822.39	1498.94
SP13	-585.59	-1418.64	-1637.78	-334.89	1510.50
SP14	-585.59	-1418.64	-1145.78	-10.39	1515.58
Sea-level position of well x = 0.00, y = 0.00					

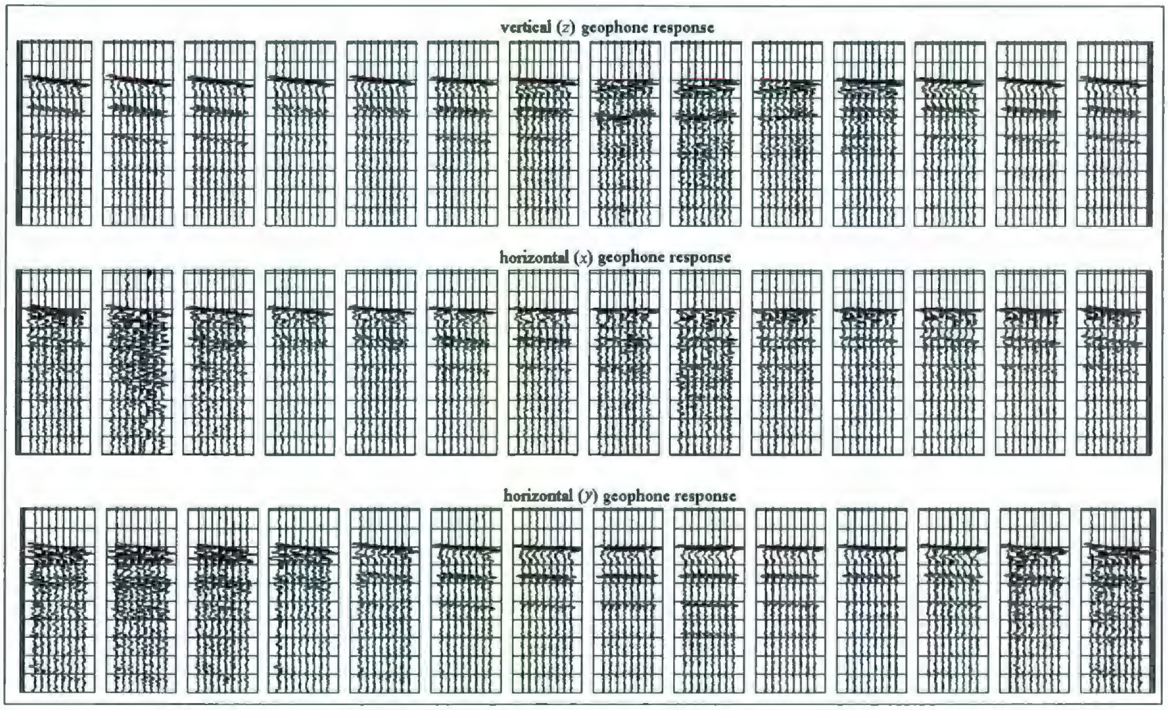


Figure 2.6: Walkaround VSP raw traces for each shot. The receiver array is comprised of an eight-string array, thus, eight traces are obtained for each shot. Each receiver package is composed of three orthogonally orientated geophones. Responses for all three geophones for each shot are shown above. Fourteen sources were placed radially around the receiver array,

2.3.3 Walkaway VSP

A plan view of the walkaway survey geometry is shown in Figure 2.7. The surveyed well was deviated 46° from vertical at the array center and aligned with the structural dip. A source line was positioned such as to be centered over the receiver array depth range. The source line was oriented 61° from the well trajectory. The source line consisted of 200 source locations with an interval of 25 m, with maximum source-receiver offsets from the center of the receiver array of 4000 m and 1000 m, in opposing directions as shown. The source consisted of a four-gun array, composed of two 100 cc plus two 150 cc air-guns, placed 6.0 m below sea level. Receivers were comprised of three-component (3C) geophones configured in a five-level array, with a spacing of 15 m between the geophones. The five-level receiver array covered a vertical depth range from 1980 m to 2020 m (MSL). Table 2.2 provides the depths for each receiver and the source-receiver spread for both source offset directions, i.e., the longside and the shortside.

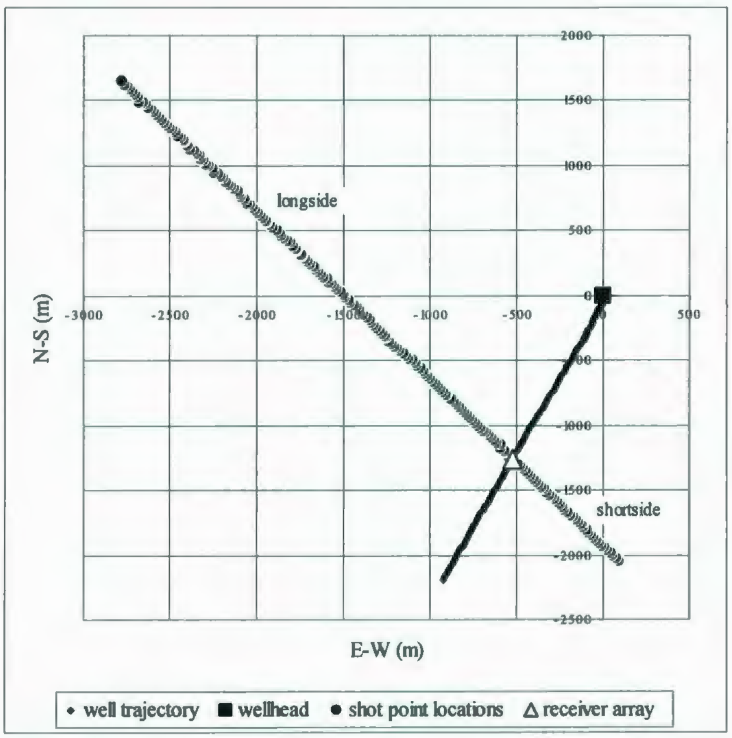


Figure 2.7: Walkaway VSP survey geometry, plan view. The angle between the well trajectory and source line is 60.7°. The wellbore inclination is 46.4° at the center of the receiver array. The source line consisted of 200 shot point locations with an interval of 25 m, with maximum source-receiver offsets from the center of the receiver array of 4000 m (longside) and 1000 m (shortside), in opposing directions.

Table 2.2: Receiver depths and spreads for walkaway VSP line. Vertical depths are to each of the five receivers of the receiver array. Maximum source-receiver offset from the center of the receiver array was 4000 m for the longside and 1000 m for the shortside.

Receiver (#)	Vertical depth (m, from source)	Source-Receiver spread (m, offset)			
		Shortside		Longside	
		Far offset	Near offset	Near offset	Far offset
1	1973.92	1014.08	76.92	74.74	3964.13
2	1983.81	1008.35	66.46	66.31	3969.12
3	1993.70	1002.71	61.00	56.20	3974.14
4	2003.76	997.09	50.09	46.36	3979.26
5	2013.93	991.55	39.17	37.13	3984.40

CHAPTER 3: DATA ACQUISITION RESULTS AND PROCESSING

3.1 ZERO-OFFSET VSP

Figure 2.4 shows the stack response for the *z*-component geophone. Only the *z*-component data were utilized, since the source is always nearly vertically above the receivers, rays are nearly vertically incident and most of the particle motion for compressional or P waves lies in the vertical plane containing the source and receiver. For P waves, particle motion is longitudinal, i.e., parallel to the direction of propagation. It consists of alternating compression and extension (dilatation), along the ray and perpendicular to the wavefront.

Each trace was corrected to account for the time from the source reference hydrophone to source position (distance between reference hydrophone and source position divided by the velocity of water: 3.5 m/1524.0 m/s). An additional time correction of 1.7 ms was applied to account for instrument delay.

First-break time picks at each depth were converted to vertical times and then referenced to the datum of mean sea level (MSL), using a correction velocity of 1524 m/s (velocity of water). Table A.1 in Appendix A, lists the depths and vertical times obtained (these traveltimes will be referred to as observed times for the zero-offset VSP).

3.2 WALKAROUND VSP

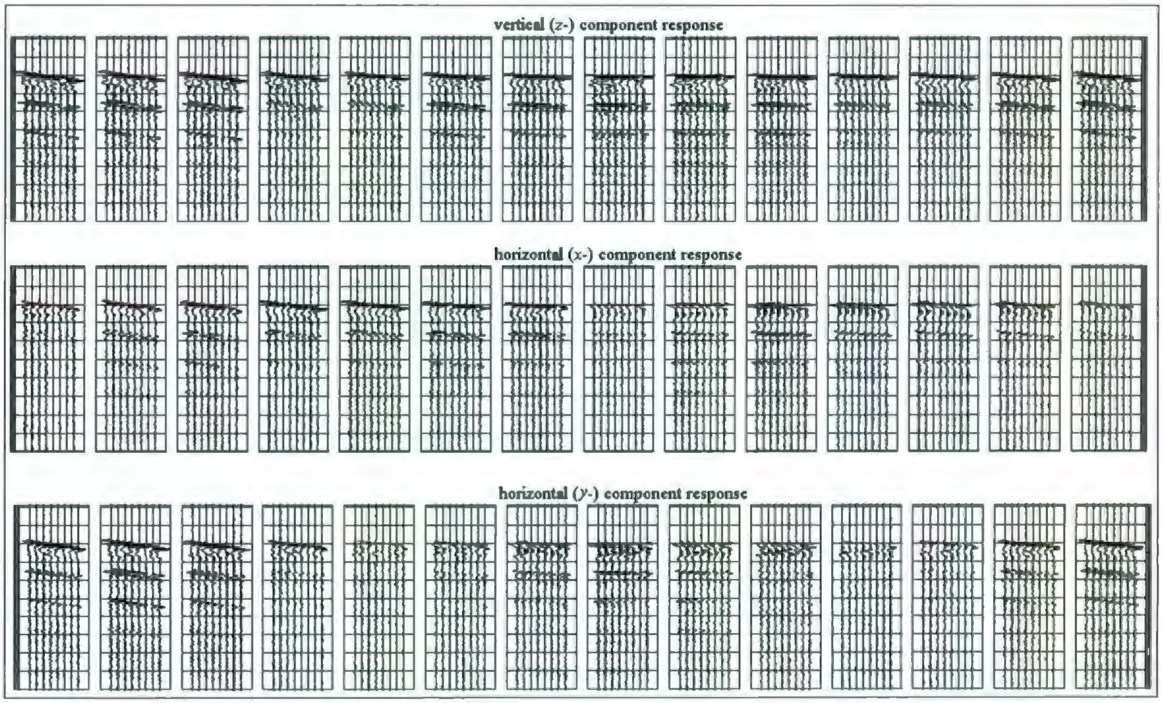


Figure 3.1: Walkaround VSP, oriented trace responses after two co-ordinate rotations. First rotation was in the direction of maximum P-wave energy in the horizontal plane and the second, in the vertical plane towards the source allowing for the separation of the P-wave component from other components and establishing the arrival direction.

The raw walkaround data, Figure 2.6, were rotated to obtain the responses in each of the three axes, i.e., vertical z (in the plane of the source-receiver) and horizontal x and horizontal y (orthogonal to each other). Two co-ordinate rotations were performed: first, in the direction of maximum P-wave energy in the horizontal plane and second, in the vertical plane towards the source allowing for the separation of the P-wave component from other components, namely shear horizontal (SH) and shear vertical (SV) and establishing the arrival direction. The methodology used is as described by DiSiena et al. (1984). Figure 3.1 shows the oriented trace responses for each shot.

Appendix B, Table B.1, provides geophone depths and corresponding traveltimes, where the measured traveltime is the traveltime from source position to receiver position, picked as the first-break time on the oriented *z*-component traces. The measured traveltimes were corrected for geometry by considering the following issues:

a) Difference in traveltimes due to length of receiver array and well deviation. Each receiver is at a slightly different position giving a different source-to-receiver distance for the same shot. Traveltimes for the same shot, therefore, vary, based on the source-to-receiver distance. A central receiver (Receiver No. 4, depth = 2176.8 m VD) was selected as reference, and the raw times corrected to a fixed source-receiver distance for each source. Figure 3.2a is a plot of the uncorrected traveltimes and the traveltimes after correction to the central receiver.

b) Each shot is also at a different physical location with a varying distance from the reference receiver. A correction was thus applied to 'normalize' the data to a fixed source-receiver distance, common to all the sources. Source No. 14 was selected for reference. Figure 3.2b is a plot of traveltimes normalized to the source and traveltimes after correction to both the central receiver and the reference source.

Appendix B shows a sample calculation for both of the above and includes a table of measured and corrected traveltimes showing the times for all shots and associated receivers.

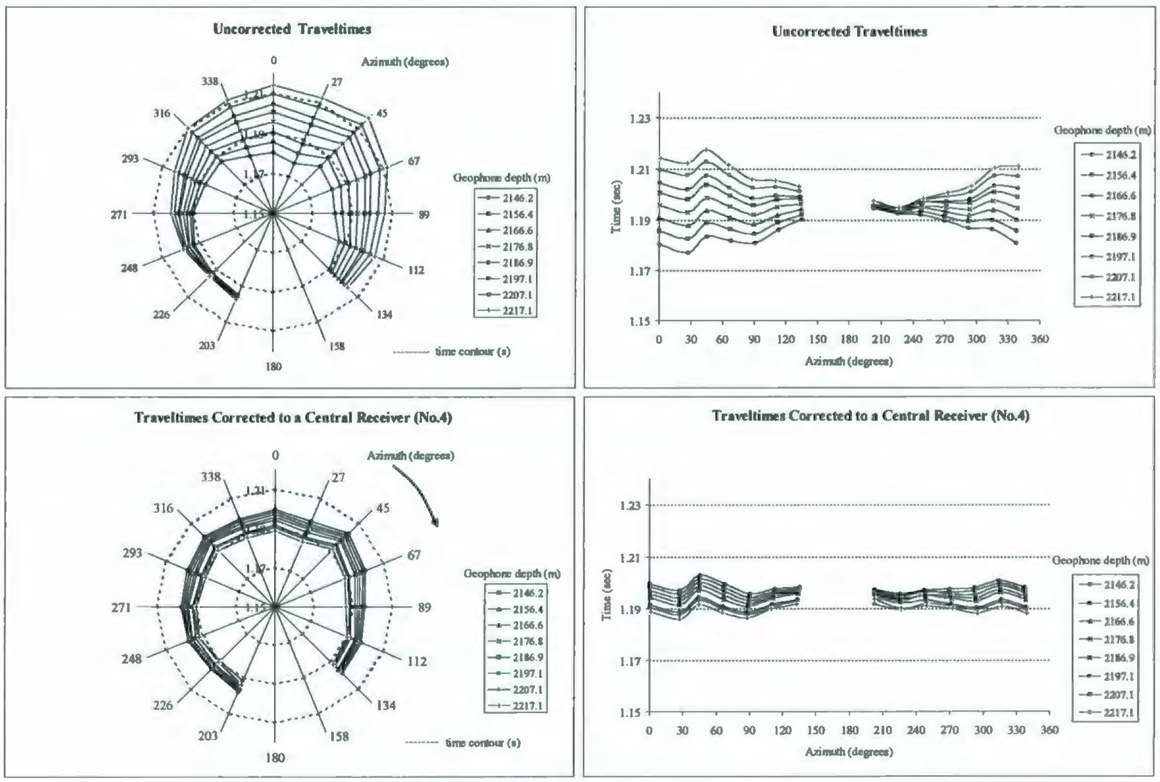


Figure 3.2a: Walkaround VSP data, traveltimes uncorrected (above) and corrected for geometry to a central receiver (below). Traveltimes were corrected for variations arising from differences between source and receiver positions due to the length of the receiver array and deviation of the well.

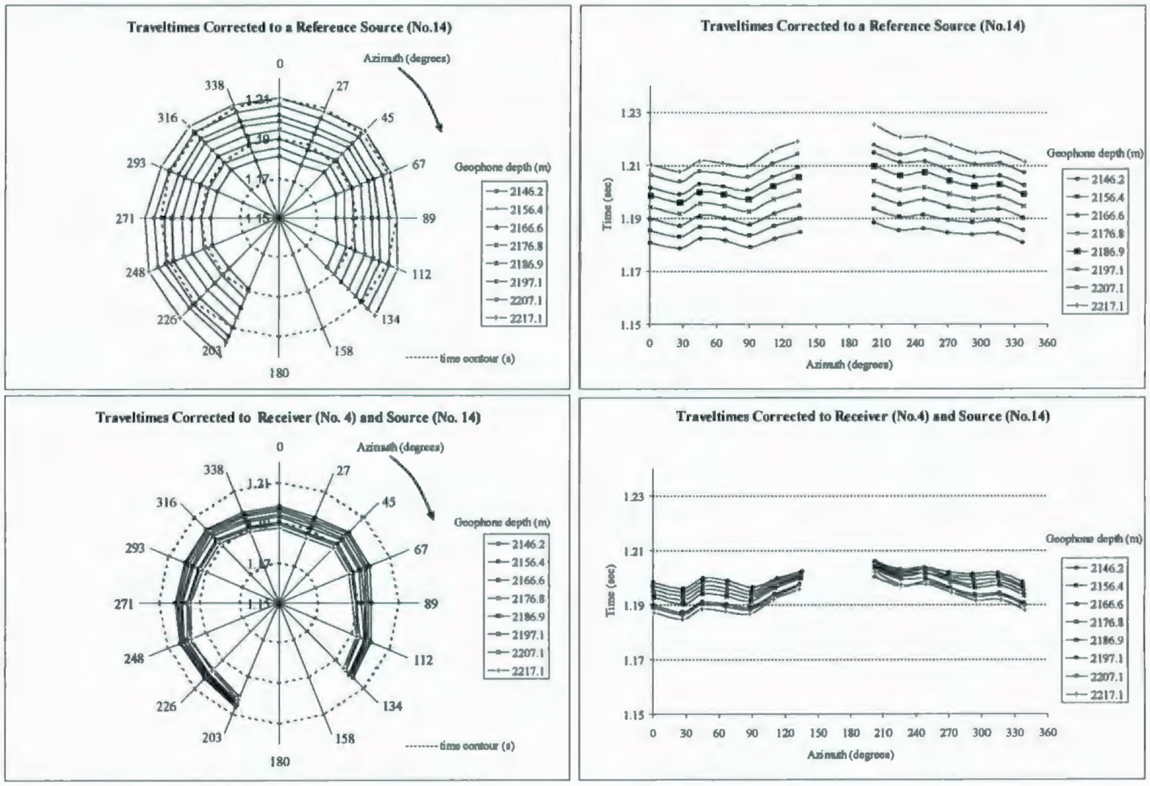


Figure 3.2b: Walkaround VSP data, normalized to a source to correct the traveltimes to a fixed source-receiver distance (above). Traveltimes were normalized to both a reference receiver (see Figure 3.2a) and subsequently to a reference source to obtain fully corrected traveltimes (below).

3.3 WALKAWAY VSP

Direct P-wave arrival times were picked at the first breaks after rotation of the vertical and horizontal components of the 3C trace data to obtain the direct P-wave component in the source-receiver plane. Data thus obtained are shown in Figure 3.3. Appendix C shows the traveltimes obtained for each of the five receivers.

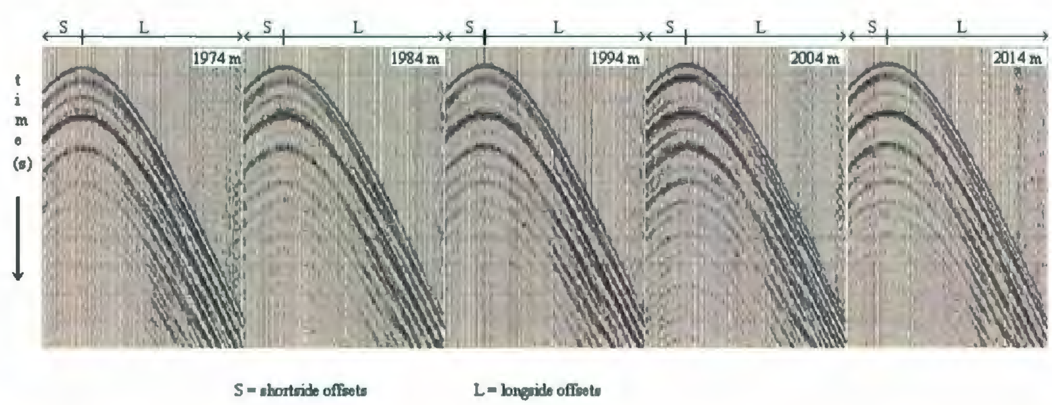


Figure 3.3: Direct P-wave component response in source-receiver plane for the walkaway VSP. Receiver depths are indicated at the top right of each panel. The maximum shortside offset was 1014 m, the maximum longside offset was 3984 m.

CHAPTER 4: SYNTHETIC DATA GENERATION

In order to gain confidence in the algorithm, evaluate its limitations and understand the results obtained using real data, synthetic data sets were generated. Some of the synthetic data sets generated and used are described in this chapter and discussed in Chapter 5 and Chapter 6. Chart 4.1 provides a summary. Traveltimes obtained from forward modelling for the synthetic data sets were used as inputs to the program to confirm that the program was able to estimate a, b and χ.

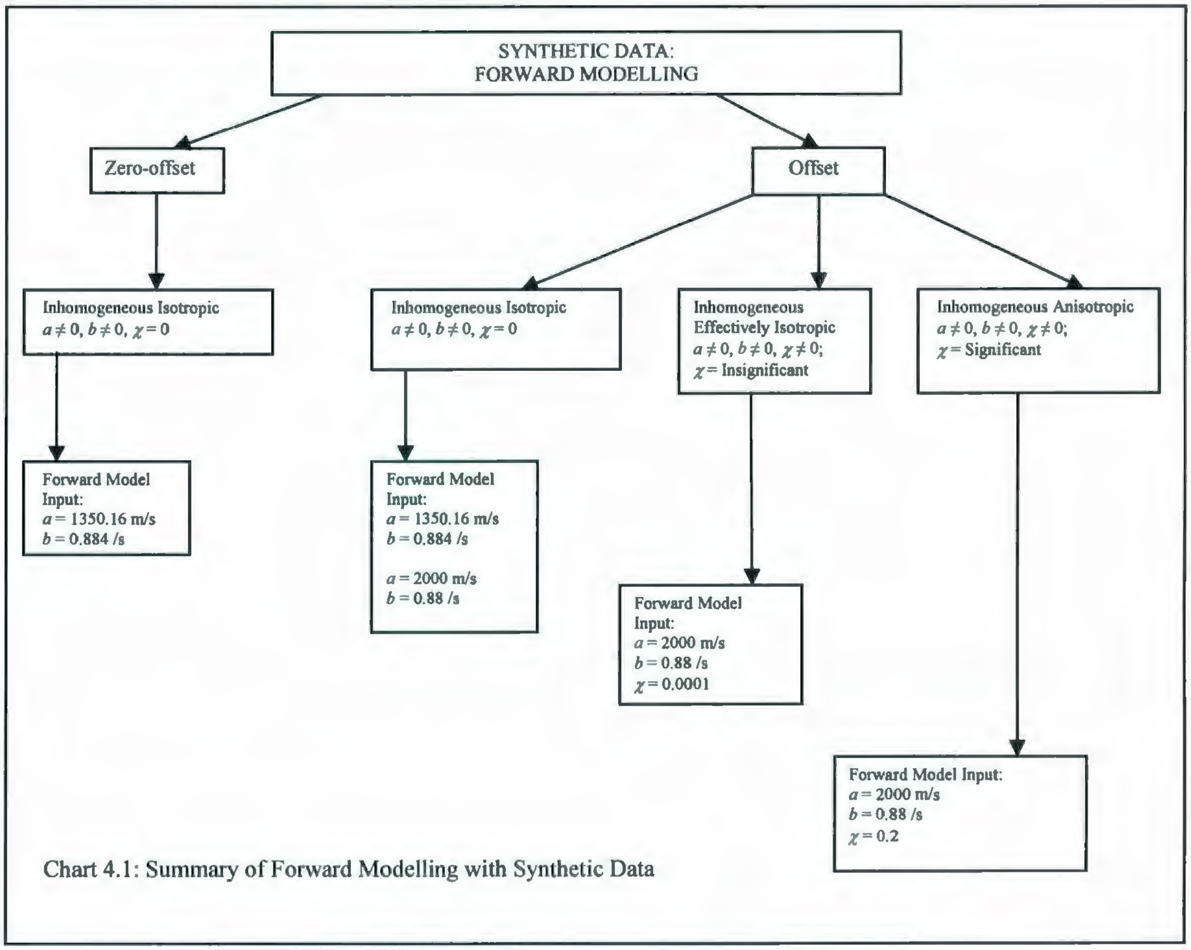


Chart 4.1: Summary of Forward Modelling with Synthetic Data

4.1 ZERO-OFFSET DATA

Data were modelled using arbitrary, but 'realistic' values for a and b (a = 1350.1624 m/s and b = 0.884 /s). In order to compute the traveltimes, depths were set in the range of 1 m to 2000 m, with offset set at 1.0 m. For each depth, the ray parameter p was calculated and subsequently, the traveltime computed, as shown in Appendix D, Table D.1. Figure 4.1 displays the traveltimes obtained for the synthetic data.

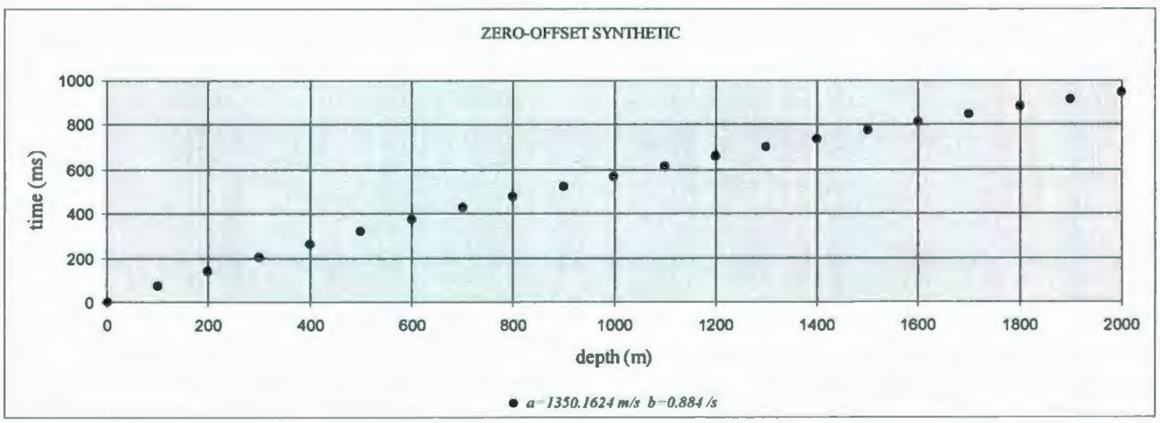


Figure 4.1: Zero-offset synthetic data. Traveltimes were computed using 'realistic' values for parameters a and b, with depths set in the range of 1 m to 2000 m, and offset set at 1.0 m. For each depth, the ray parameter p was calculated and subsequently, the traveltime computed.

4.2 OFFSET DATA

Several synthetic offset data sets were generated with values for *a*, *b* and χ as below:

1. $\chi = 0$. The same values as above for *a* and *b* (a = 1350.1624 m/s and b = 0.884 /s). And, a = 2000 m/s, b = 0.88 /s.
2. Introduction of insignificant χ, a = 2000 m/s, b = 0.880 /s and χ = 0.0001.
3. Introduction of significant χ, a = 2000 m/s, b = 0.880 /s and χ = 0.2.

Depths were fixed at 1960 m, 1970 m, 1980 m, 1990 m, and 2000 m. Offsets ranged from 900 m to 2700 m at 100 m intervals. For each receiver depth and offset pair, the ray parameter *p* was calculated and subsequently, the traveltime computed. Appendix D, Tables D.2 to D.5, show the synthetic data traveltimes with offset obtained at each of the receiver depths. Figures 4.2 to 4.4 display the traveltimes with offset for each of the above cases.

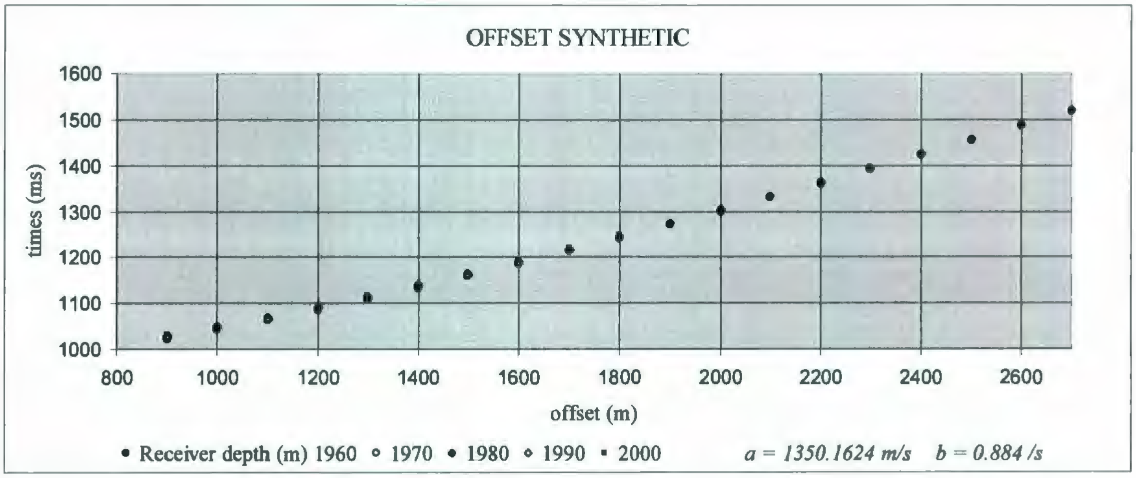


Figure 4.2a: Offset synthetic data. Traveltimes were computed using 'realistic' values for parameters a and b for isotropic conditions: $\chi = 0$, $a = 1350.1624$ m/s and $b = 0.884$ /s.

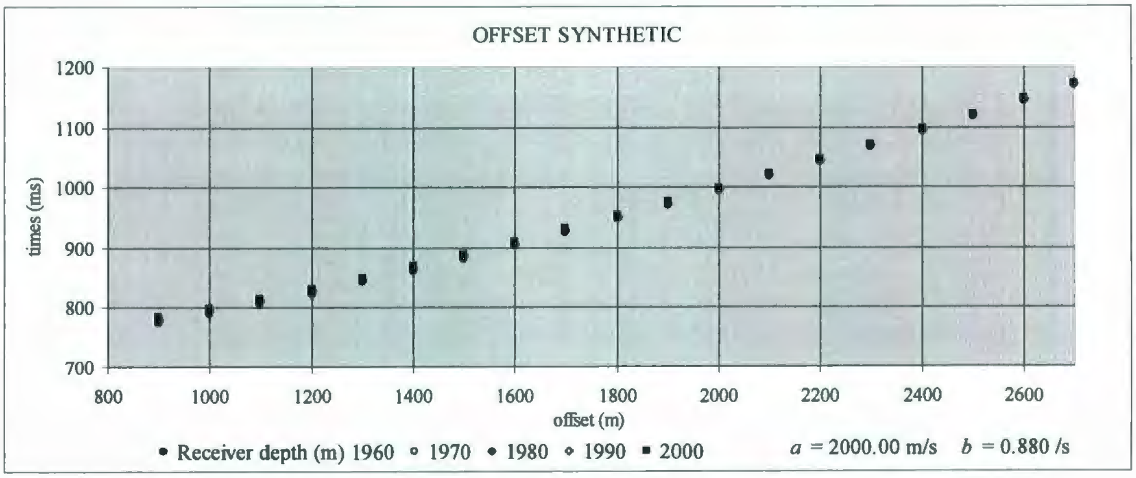


Figure 4.2b: Offset synthetic data. Forward modelling for traveltimes expected. Isotropic conditions: $\chi = 0$, $a = 2000.00$ m/s and $b = 0.880$ /s.

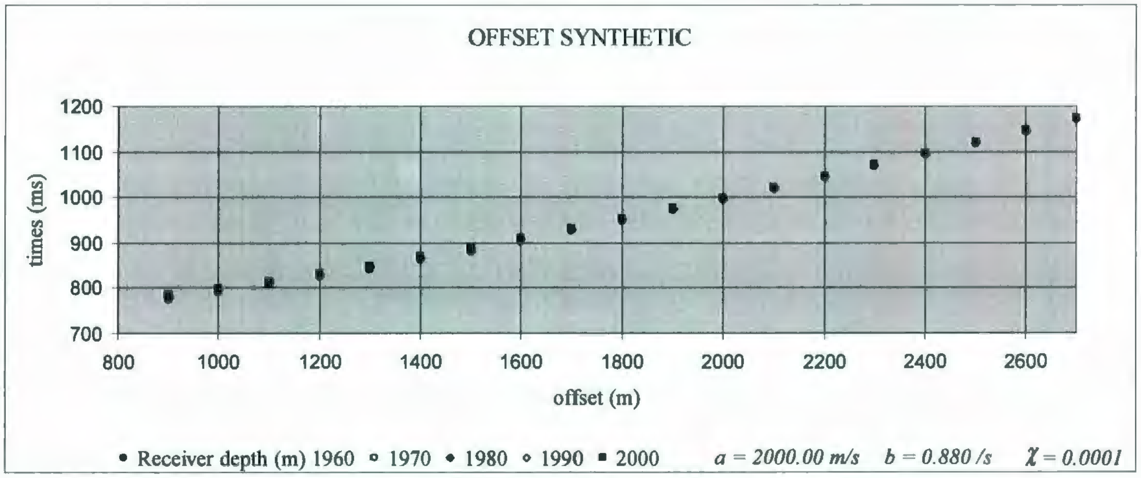


Figure 4.3: Offset synthetic data, with χ set to a very small value. Insignificant χ, $a = 2000.00$ m/s, $b = 0.880$ /s and $\chi = 0.0001$.

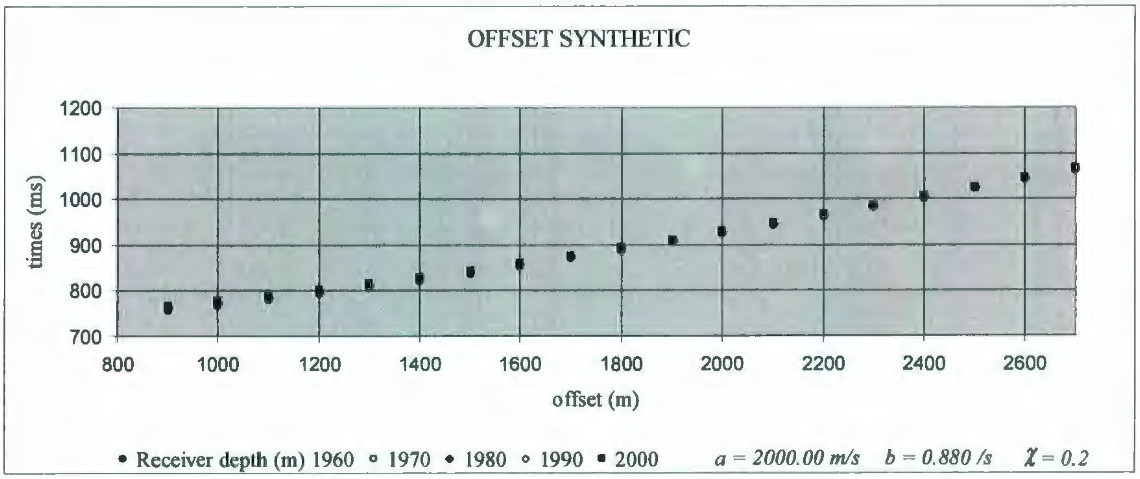


Figure 4.4: Offset synthetic data, with χ set to a large value. Significant χ, $a = 2000.00$ m/s, $b = 0.880$ /s and $\chi = 0.2$.

CHAPTER 5: PROGRAM APPLICATION

5.1 PROGRAM DESCRIPTION

The algorithm is based on the traveltime expression derived by integrating along the z-axis. As explained in Sections 1.1 and 1.3.5, and as shown by the results, this expression was found to be valid up to the turning points of rays.

The direct-arrival traveltime between a source at the origin, (0, 0), and a receiver located at (X, Z) in an elliptically anisotropic medium with inhomogeneity given by a constant velocity gradient, and obtained by integration along the z-axis, as described by expression (1.2), is:

$$t=\frac{1}{b}\ln\left[\frac{a+bz}{a}\frac{1+\sqrt{1-p^2a^2(1+2\chi)}}{1+\sqrt{1-p^2(a+bz)^2(1+2\chi)}}\right].$$

An algorithm developed, by Slawinski (2003), to determine the values of a, b, and χ using the analytic traveltime expression above was applied to synthesized and observed field data and the results evaluated.

The procedure involves the regression analysis to solve for the vector composed of the model parameters to be estimated [a, b, χ]. The objective in estimating this vector is to minimize the sum of squared residuals for a number of observations. The residuals are defined as $\varepsilon_i = T_i - t_i(\mathrm{P})$, where T_i indicates the observed traveltime, t_i indicates the modelled traveltime and where $\mathrm{P} = [a, b, \chi]$ is the vector composed of the model parameters to be estimated. The traveltime expression is a nonlinear function with respect to the parameters a, b and χ given by $t_i = t(\mathrm{X}_i; a, b, \chi)$, for a given receiver, $\mathrm{X}_i = [\mathrm{X}, \mathrm{Z}]_i$.

The expression is linearized about initial guesses for a, b, χ to enable the use of Gauss-Newton optimization. If the initial parameter estimates is denoted P^0, linearization is achieved by taking the first-order Taylor series expansion of the model centred on P^0 and collecting the partial derivatives as elements of the Jacobian matrix, J_{ij}, with $i = 1 \ldots n$, for n observations and $j = 1, 2, 3$, since there are three parameters. The Jacobian matrix is orthogonalized and the squared residuals are set to be minimized in solving for P. This value for P is used as the starting point for a new minimization, i.e., setting $\mathrm{P} = \mathrm{P}^0$ and solving for P again. The process is iterated until an acceptable difference between two consecutive estimates is obtained giving the final estimate of P.

5.2 PROGRAM EXECUTION WITH SYNTHETIC DATA

Results obtained using synthetic data are summarized in Chart 5.1.

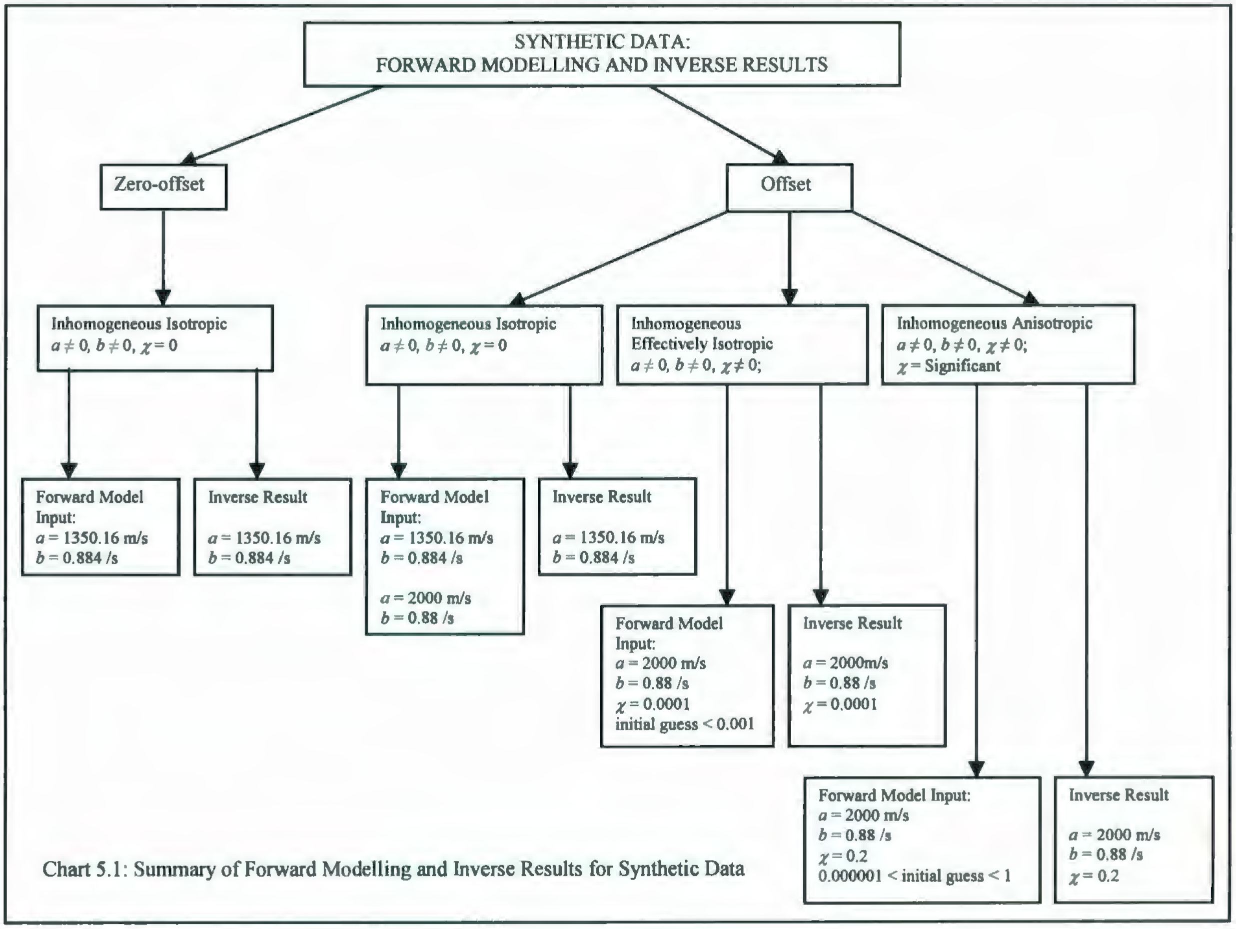


Chart 5.1: Summary of Forward Modelling and Inverse Results for Synthetic Data

5.2.1 Zero-offset Data

Traveltimes computed as described in section 4.1 from forward modelling, for zero-offsets, were used as inputs. Results obtained are shown in Table 5.1. The inverse obtained is a very close estimate of the forward parameters used. This verifies that in an isotropic medium or two-parameter case, using traveltimes that vary with increasing depth, the program is able to determine the correct values.

Table 5.1: Forward model parameters and corresponding inverse result, isotropic medium, zero-offset data.

Forward Model:		Inverse:		
				Std error
$a =$	1350.1624	$a =$	1350.1623982	0.0000002179
$b =$	0.8840081182	$b =$	0.8840081172	0.0000000004

5.2.2 Offset Data. Isotropic Case (*a* and *b* only)

Traveltimes from forward modelling for the two-parameter case, with the same values of a and b as for the zero-offset synthetic, but with fixed depth points and with offset varying as described in section 4.2, were used for the first offset synthetic generated. Results obtained are shown in Table 5.2. Again, the inverse obtained is a very close estimate of the forward parameters used. This verifies that in an isotropic medium, or two-parameter case, using traveltimes that vary with increasing depth and varying offsets, the program is able to determine the correct values.

Table 5.2: Forward model parameters and corresponding inverse result, isotropic medium, offset data.

Forward Model:		Inverse:		
				Std error
$a =$	1350.1624	$a =$	1350.1599999	0.0000000736
$b =$	0.8840081182	$b =$	0.8840000001	0.0000000001
$a =$	2000.0000	$a =$	1999.9999999	0.0000001633
$b =$	0.8800000000	$b =$	0.8800000001	0.0000000002

5.2.3 Offset Data. Isotropic Case (*a* and *b* with $\chi = 0.0001$)

We now introduce χ into the computation by setting χ to be very small, $\chi = 0.0001$, so that effectively the medium can still be considered to be isotropic. Forward model parameters used and traveltimes computed are shown in Table D.4 (Appendix D).

It was found that to get the correct estimate of χ, the initial guess must be close to the real value of χ. Results obtained with different initial guesses used for χ are shown in Table 5.3. If the initial guess for χ is set at the program's default value of 0.15 or is more than an order of a magnitude larger than the true value, then erroneous estimates of

χ are obtained. To test this further, χ was set to 0.2 in the forward model and inverses with different initial guesses for χ were determined as described in the next section.

Table 5.3: Isotropic case. Forward model parameters and corresponding inverse results. Initial guess must be close to the real value of χ otherwise erroneous estimates of χ are obtained.

Forward Model:	a = 2000 m/s	b = 0.88 /s	$\chi = 0.0001$			
Initial guess for χ	Inverse					
				Std error		
	a	b	χ	a	b	χ
0.00001	2000.0000000000	0.8800000000	0.00010000000000	0.000000000036605	0.000000000000050	0.000000000000006
0.0001	2000.0000000000	0.8800000000	0.00010000000000	0.000000000036745	0.000000000000050	0.000000000000006
0.0002	2000.0000000000	0.8800000000	0.00010000000000	0.000000000036407	0.000000000000049	0.000000000000006
0.001	2000.0000000000	0.8800000000	0.00010000000000	0.000000000036534	0.000000000000050	0.000000000000006
0.01	1999.0452425635	1.0214756716	0.02000000000000	1072.636572541470	1.502230009405290	0.187355079856705
0.1	2011.3831762326	0.9960483381	0.20000000000000	3301.455476564300	4.462177461117350	0.596034792545728
0.15	2027.0340674882	0.9727653926	0.30000000000000	4623.930334625430	6.155176718867170	0.848081928220989
0.2	2045.5807848963	0.9465424877	0.40000000000000	5897.423768138920	7.745744511062770	1.096957680275070
0.5	2143.3370118166	0.8149485213	1.00000000000000	11075.53712588560	13.82534253533750	2.298159089249880
1	2164.3678578951	0.7853808634	2.00000000000001	14618.80359180340	18.02044964526430	4.392562185311780

5.2.4 Offset Data. Anisotropic Case (*a* and *b* with $\chi = 0.2$)

Forward model parameters used and traveltimes computed are shown in Table D.5 (Appendix D). Results obtained with different initial guesses used for χ are shown in Table 5.4. Again we see that if the initial guess is either too small or too large, then erroneous estimates of χ are obtained. However, given a reasonable initial guess of χ, the program is able to determine the correct values for *a*, *b* and χ.

Table 5.4: Anisotropic case. Forward model parameters and corresponding inverse results. Initial guess must be close to the real value of χ otherwise erroneous estimates of χ are obtained.

Forward Model:	a = 2000 m/s	b = 0.88 /s	χ = 0.2			
Initial guess for χ	Inverse					
				Std error		
	a	b	χ	a	b	χ
0.0000001	1980.85500451360	0.950111938958272	0.0524288000000000	747.11440007743400	1.0234886649109900	0.1285695465059010
0.000001	1999.87784299206	0.880131810360523	0.1999664526225400	0.3610355752542300	0.0004755848421768	0.0000616644396682
0.00001	1999.99999999996	0.880000000000047	0.1999999999999950	0.0000000000395533	0.0000000000000521	0.0000000000000068
0.0001	1999.99999999997	0.880000000000038	0.1999999999999960	0.0000000000380363	0.0000000000000501	0.0000000000000065
0.0002	1999.99999999997	0.880000000000041	0.1999999999999960	0.0000000000387517	0.0000000000000510	0.0000000000000066
0.001	1999.99999999997	0.880000000000045	0.1999999999999950	0.0000000000388022	0.0000000000000511	0.0000000000000066
0.01	1999.99999999997	0.880000000000045	0.1999999999999950	0.0000000000384542	0.0000000000000507	0.0000000000000066
0.1	1999.99999999997	0.880000000000045	0.1999999999999950	0.0000000000383812	0.0000000000000506	0.0000000000000066
0.15	1999.99999999997	0.880000000000039	0.1999999999999960	0.0000000000385914	0.0000000000000508	0.0000000000000066
0.2	1999.99999999997	0.880000000000044	0.1999999999999950	0.0000000000386759	0.0000000000000509	0.0000000000000066
0.5	1999.99999999997	0.880000000000045	0.1999999999999950	0.0000000000385627	0.0000000000000508	0.0000000000000066
1	2102.84204264970	0.874725470565358	2.0000000000000100	10769.320593084400	13.596359035753300	3.5233547281249900

5.3 PROGRAM EXECUTION WITH REAL DATA

As mentioned earlier, and shown in Figure 2.7, the walkaway source line consisted of 200 source locations with an interval of 25 m, with maximum source-receiver offsets from the center of the receiver array of approximately 4000 m and 1000 m, in opposing directions. In total, for this source line, there are 1000 observations (5000 m/ 25 m x 5 = 1000), since the data were simultaneously acquired in five geophones. For convenience, we will call the data with source positions out to 4000 m, in the northwest direction, as the 'longside' and in the southeast directions with offsets to 1000 m, as the 'shortside', see Figures 2.7 and 5.1. The full data set was considered as comprised of six (6) segments for convenience, as follows, and as sketched in Figure 5.1:

Segment A: Offsets on the 'longside' from 0 to 3398 m

Segment B: Offsets on the 'shortside' from 0 to 1014 m

Segment B': Offsets on the 'longside' from 0 to 1014 m, i.e., complement to Segment B

Segment C: Offsets on the 'longside' greater than 3398 m and up to 3984 m

Segment D: Offsets on the 'longside' greater than 2848 m and up to 3398 m

Various permutations of the data and combinations of the above were utilized as sub-sets of the full data set as listed below:

1. Full data set: A+B+C.
2. Very far offsets omitted: A+B.
3. Longside only, shortside omitted: A+C.
4. Shortside and very far offsets omitted: A.
5. Shortside only: B.
6. Shortside complement on longside: B'.
7. Limited offset range: D.
8. Longside, longoffsets: D+C.

The full data set, A+B+C, has maximum source offset of 3984 m. Offsets greater than 3398 m, segment C in Figure 5.1, were considered as very far offsets due to the possibility of having near-horizontal arrivals or refracted arrivals from these offsets. The parameters a, b and χ were determined for the above segments with systematically increasing offsets. The parameters a and b were also determined with χ set to zero ($\chi = 0$).

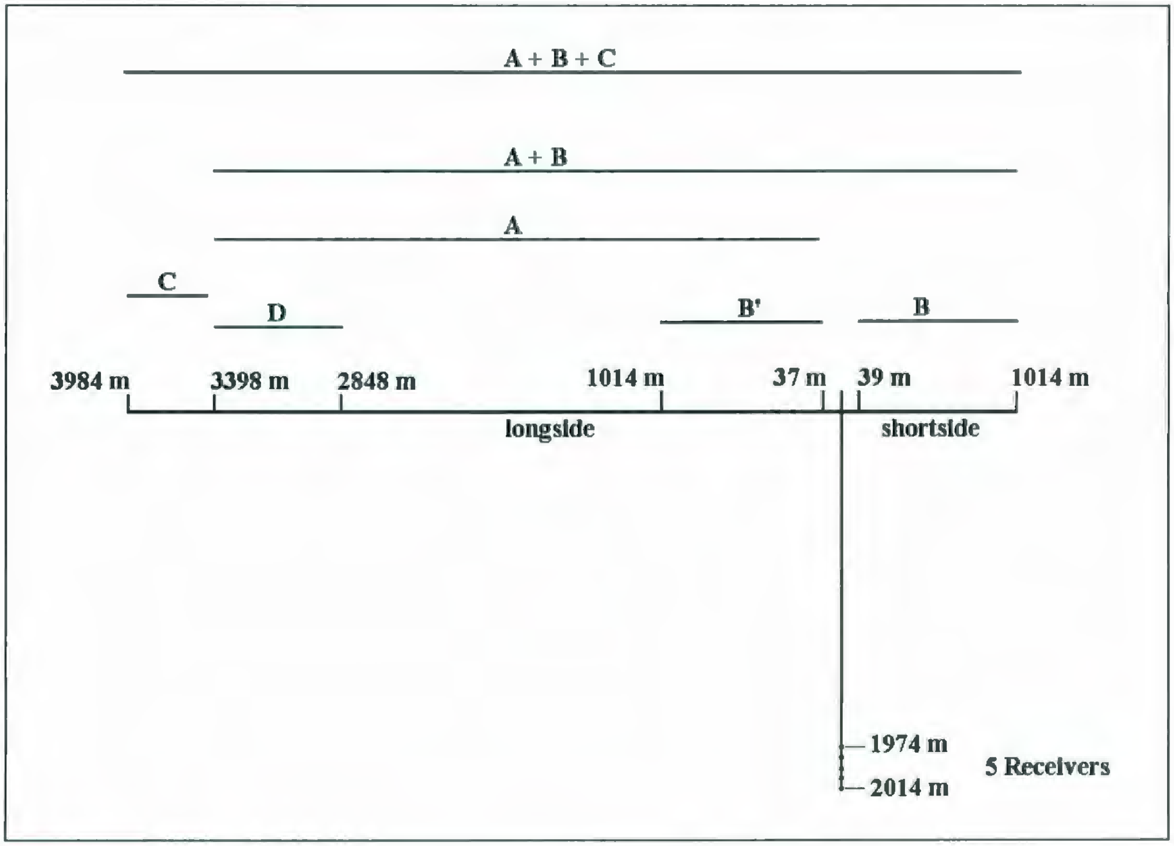


Figure 5.1: Sketch of data permutations used based on source offsets. A+B+C = full data set. A+C = longside, B = shortside.

5.3.1 Zero Offset

Using depths and traveltimes for the zero-offset VSP, as per Table A.1 (Appendix A), with offset set to 0.1 m, results obtained for the two-parameter case (*a* and *b* only) are shown in Table 5.5.

Table 5.5: Inverse result for zero-offset (vertical incidence) VSP.

		std error
$a =$	1592.258651185210	5.310555822212610
$b =$	0.575514064006845	0.007231503177721

5.3.2 Offset

Results obtained are tabulated and displayed as listed below. The results are discussed in Chapter 6 in the sections indicated.

5.3.2.1 Isotropic Cases: Inverse Results for *a*, *b*, with $\chi = 0$

1. Table E.1 and Figure 5.2: *a, b,* and $\chi = 0$, with maximum offsets increasing from 47.9 m to 3984.4 m, for all receivers, includes the longside and shortside (A+B+C). Results are discussed in section 6.3.1.

2. A subset of this data, the longside was used because of dip considerations as discussed in section 6.3.1. Table E.2 and Figure 5.3: *a, b,* and $\chi = 0$, with maximum offsets increasing from 74.7 m to 3984.4 m, for all receivers, includes the longside only (A+C). Results are discussed in section 6.3.2. Comparing Figure 5.2 with Figure 5.3 and Table E.1 with E.2, it can be seen that values obtained for *a,* and *b* are slightly different.

3. Table E.3 and Figure 5.4: *a, b,* and $\chi = 0$, with maximum offsets increasing from 2849.9 m to 3984.4 m, for all receivers, for the longside, longoffsets only (D+C). Results are discussed in section 6.3.4.

4. Table E.4 and Figure 5.5: *a, b,* and $\chi = 0$, with maximum offsets increasing from 73.2 m to 1014.1 m, for all receivers, for the shortside only (B). Results are discussed in sections 6.3.1 and 6.3.4.

5. Table E.5 and Figure 5.6: *a, b,* and $\chi = 0$, with maximum offsets increasing from 74.7 m to 1014.4 m, for all receivers, for the longside, shortoffsets only (B'). This is the same as Table E.2 and Figure 5.3 (from 2. above) up to the offset of 998.0 m, and is included here so that a direct comparison can be made with results for the shortside only (B). Figures 5.5 and 5.6 are combined as Figure 6.6 and discussed in section 6.3.1 and section 6.3.4.

5.3.2.2 Anisotropic Cases: Inverse Results for *a*, *b*, and χ

1. Table E.6 and Figure 5.7: *a, b,* and χ, for the full data set, all receivers all offsets, longside plus shortside, with maximum offsets increasing from 47.9 m to 3984.4 m (A+B+C).

2. Table E.7 and Figure 5.8: *a, b,* and χ, with maximum offsets increasing from 69.7 m to 3984.4 m, for all receivers, for the longside only (A+C). As for the isotropic case, above, a subset of this data, the longside, was used because of dip considerations. Comparing Figure 5.7 with Figure 5.8 and Table E.6 with E.7, it can be seen that values for *a, b,* and χ obtained are slightly different. Results are discussed further in sections 6.3.1, 6.3.3 and 6.3.4.

3. Table E.8 and Figure 5.9: *a, b,* and χ, with maximum offsets increasing from 2849.9 m to 3984.4 m, for all receivers, for the longside, longoffsets only (D+C). Results are discussed in section 6.3.4.

4. Table E.9 and Figure 5.10: *a, b,* and χ, with maximum offsets increasing from 99.6 m to 1014.1 m, for all receivers, for the shortside only (B). Figures 5.10 and 5.11 are combined as Figure 6.7 and discussed in section 6.3.1.

5. Table E.10 and Figure 5.11: *a, b,* and χ, with maximum offsets increasing from 69.7 m to 1014.4 m, for all receivers, for the longside, shortoffsets only (B'). This is the same as Table E.2 and Figure 5.3 (from 2. above) up to the offset of 998.0 m, and is included here so that a direct comparison can be made with results for the shortside only (B). Figures 5.10 and 5.11 are combined as Figure 6.7 and discussed in section 6.3.1.

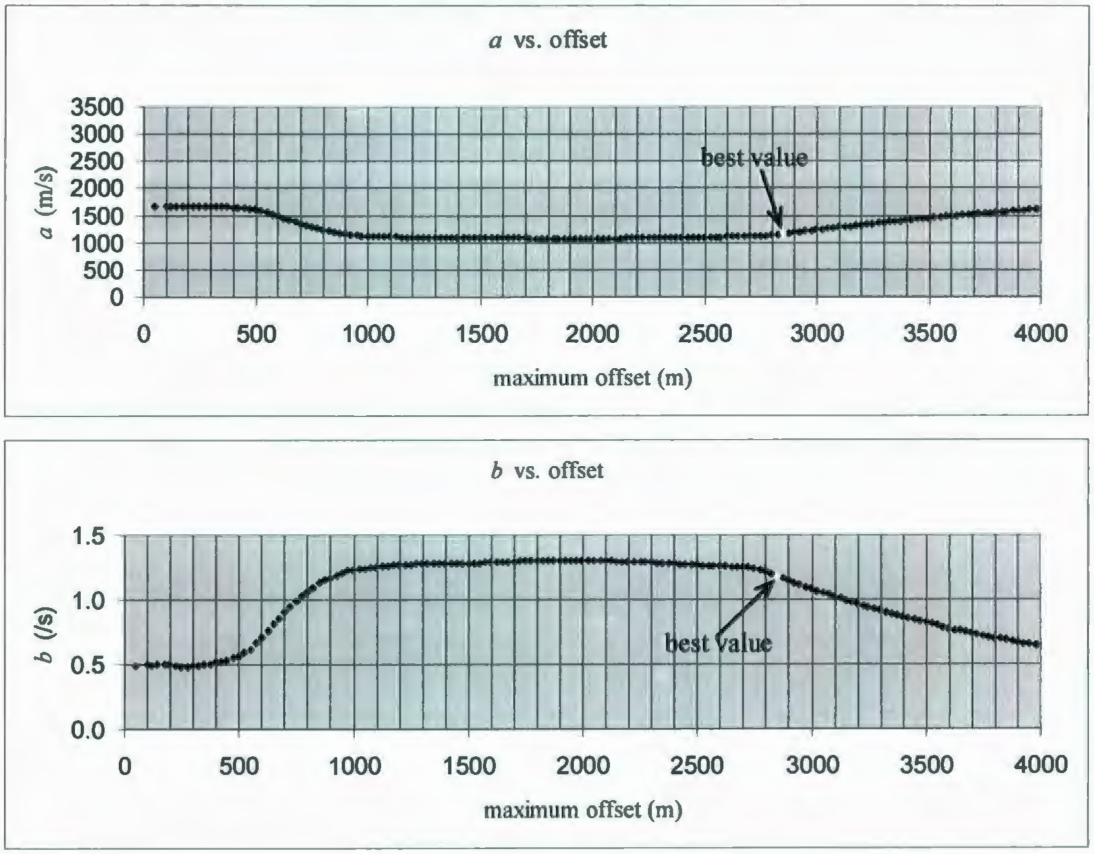
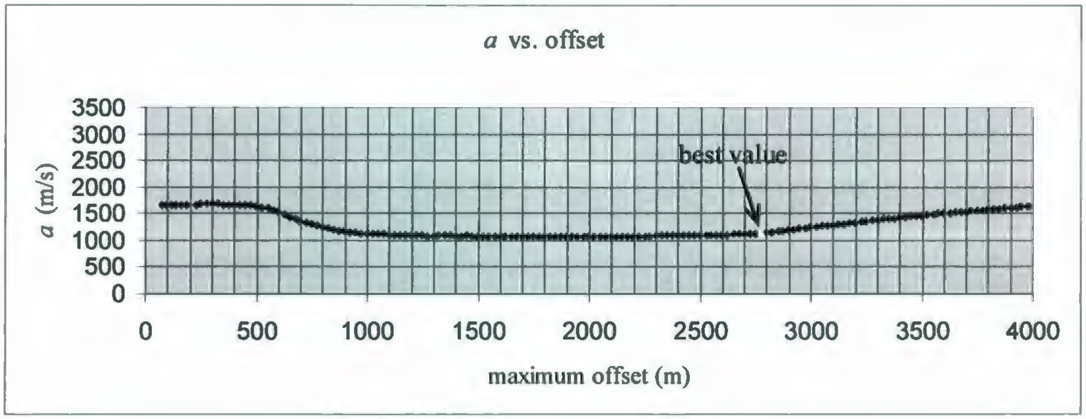


Figure 5.2: Display of results (from Table E.1) of a, b, and $\chi = 0$, with maximum offsets increasing from 47.9 m to 3984.4 m, for all receivers, includes the longside and shortside, (A+B+C). Best values (minimum standard error) are as indicated.



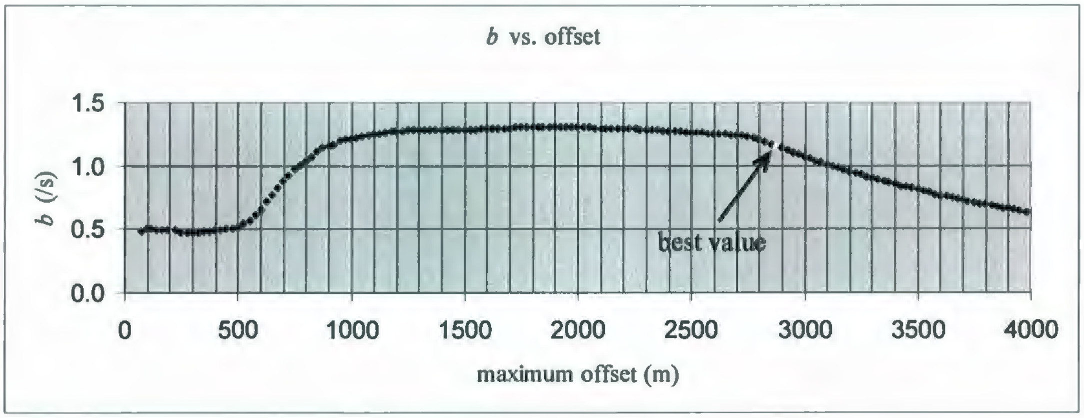


Figure 5.3: Display of results (from Table E.2) of *a*, *b*, and $\chi = 0$, with maximum offsets increasing from 74.7 m to 3984.4 m, for all receivers, includes the longside only, (A+C). Best values (minimum standard error) are as indicated.

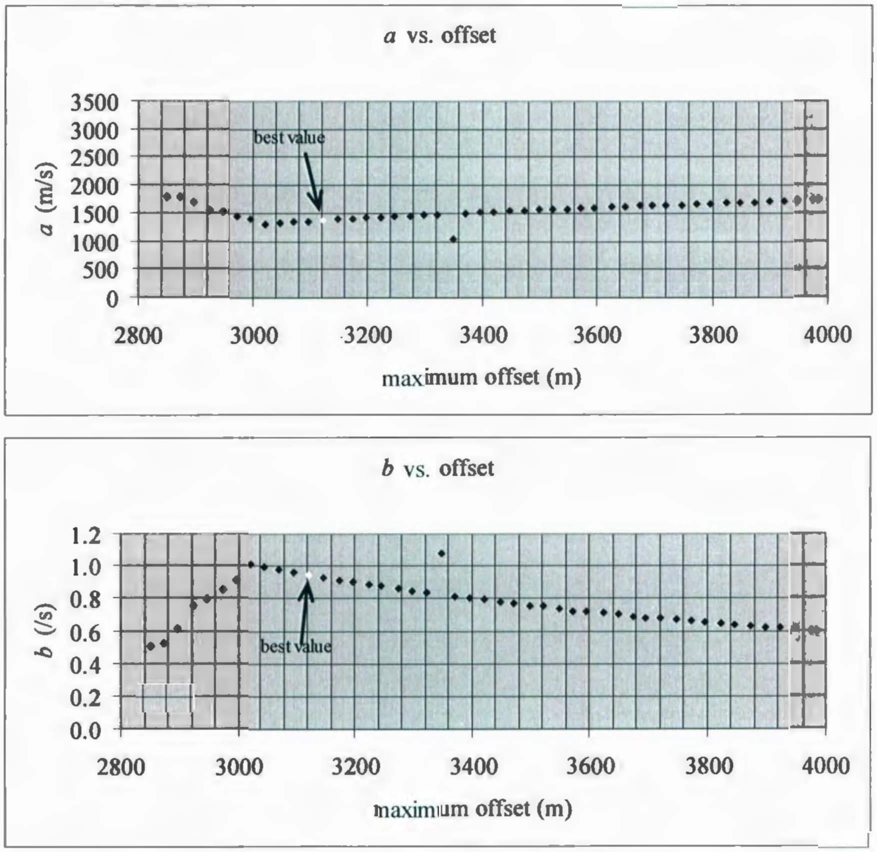


Figure 5.4: Display of results (from Table E.3) of a, b, and $\chi = 0$, with maximum offsets 2849.9 m to 3984.4 m, for all receivers, for the longside, longoffsets only, (D+C). Best values (minimum standard error) are as indicated.

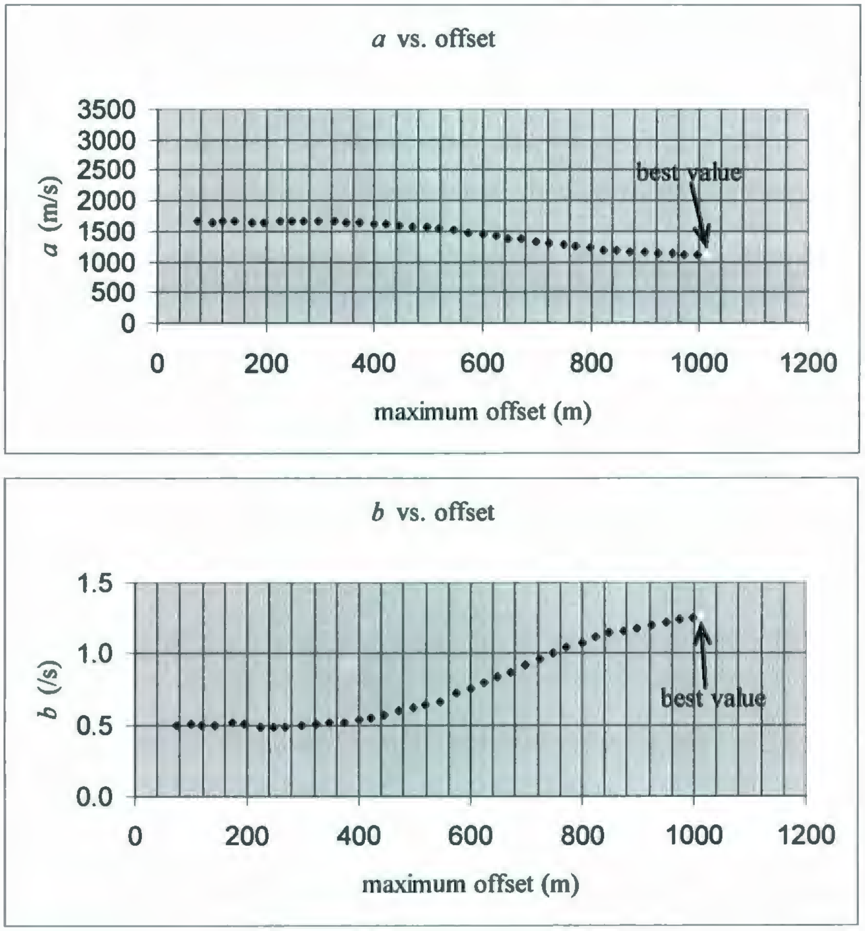


Figure 5.5: Display of results (from Table E.4) of a, b, and $\chi = 0$, with maximum offsets increasing from 73.2 m to 1014.1 m, for all receivers, for the shortside only, (B). Best values (minimum standard error) are as indicated.

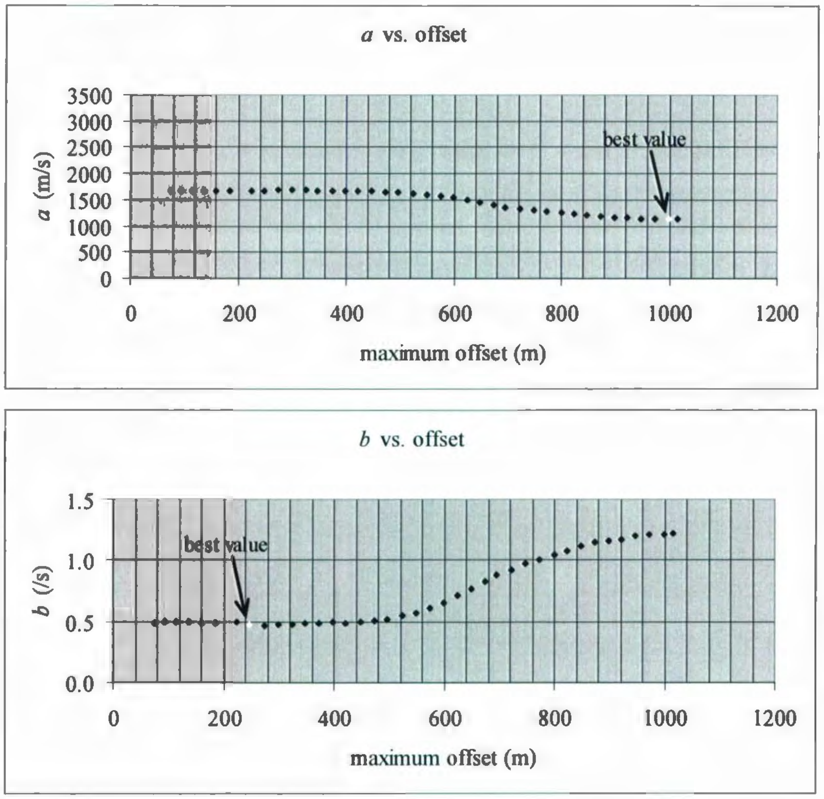


Figure 5.6: Display of results (from Table E.5) of a, b, and $\chi = 0$, with maximum offsets increasing from 74.7 m to 1014.4 m, for all receivers, for the longside, shortoffsets only (B'). This is the same as Figure 5.8 up to the offset of 998.0 m, and is included here for comparison with results for the shortside only (B), Figure 5.10. Best values (minimum standard error) are as indicated.

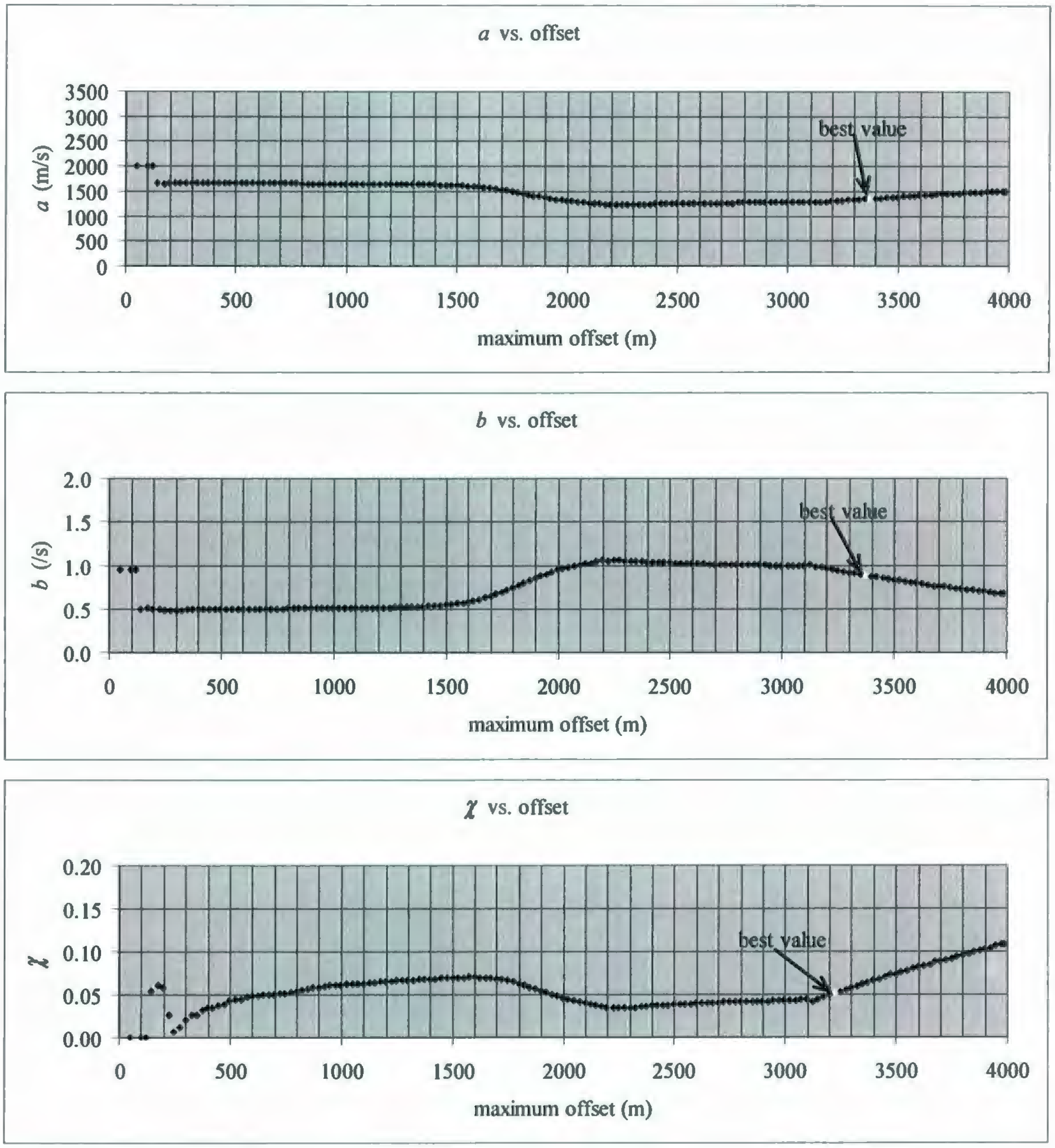


Figure 5.7: Display of results (from Table E.6) of *a*, *b*, and χ, with maximum offsets increasing from 47.9 m to 3984.4 m, includes longside and shortside, (A+B+C). Best values (minimum standard error) are as indicated.

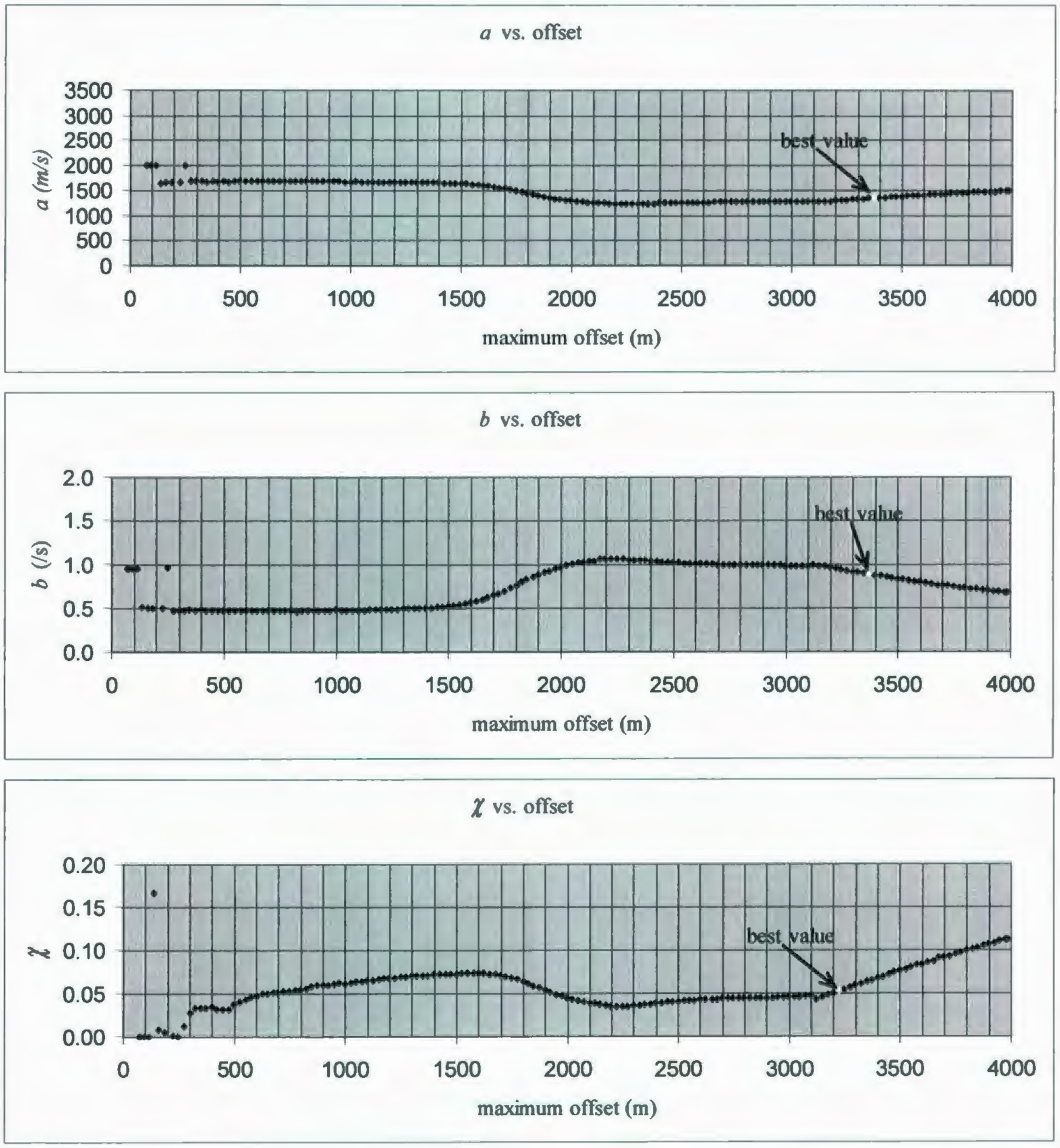


Figure 5.8: Display of results (from Table E.7) of a, b, and χ, with maximum offsets increasing from 69.7 m to 3984.4 m, for all receivers, for the longside only, (A+C). Best values (minimum standard error) are as indicated.

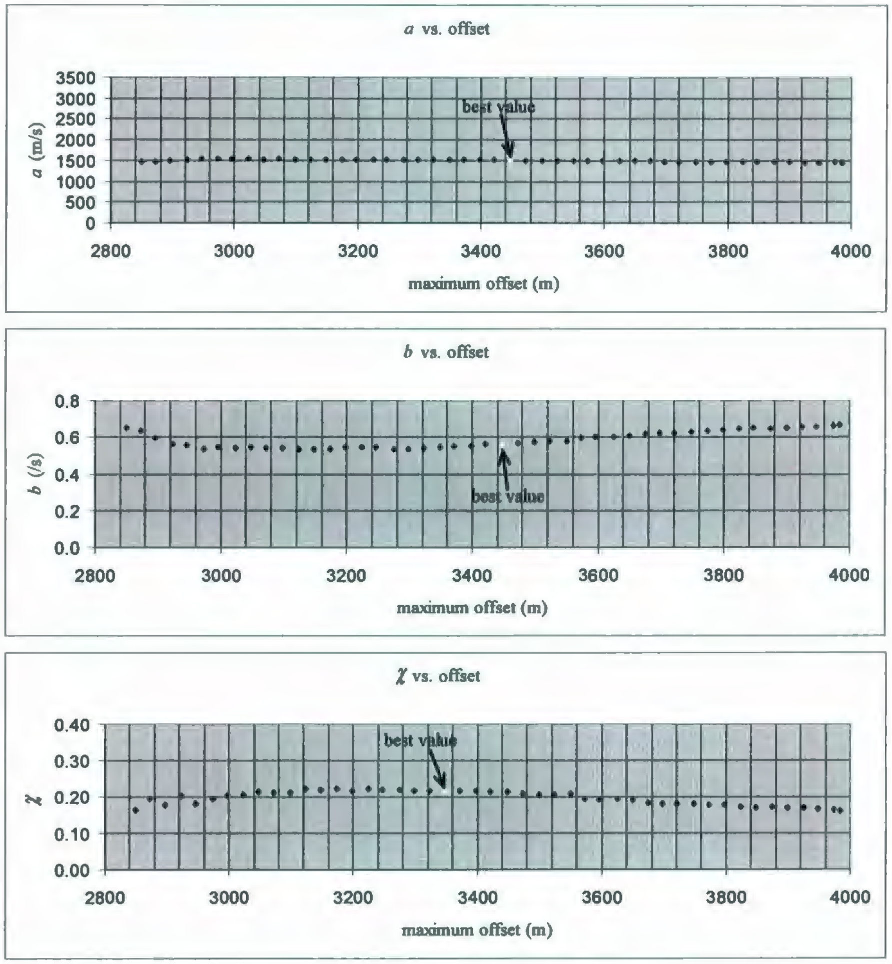


Figure 5.9: Display of results (from Table E.8) of *a*, *b*, and χ, with maximum offsets increasing from 2849.9 m to 3984.4 m, for all receivers, for the longside, longoffsets only, (D+C). Best values (minimum standard error) are as indicated.

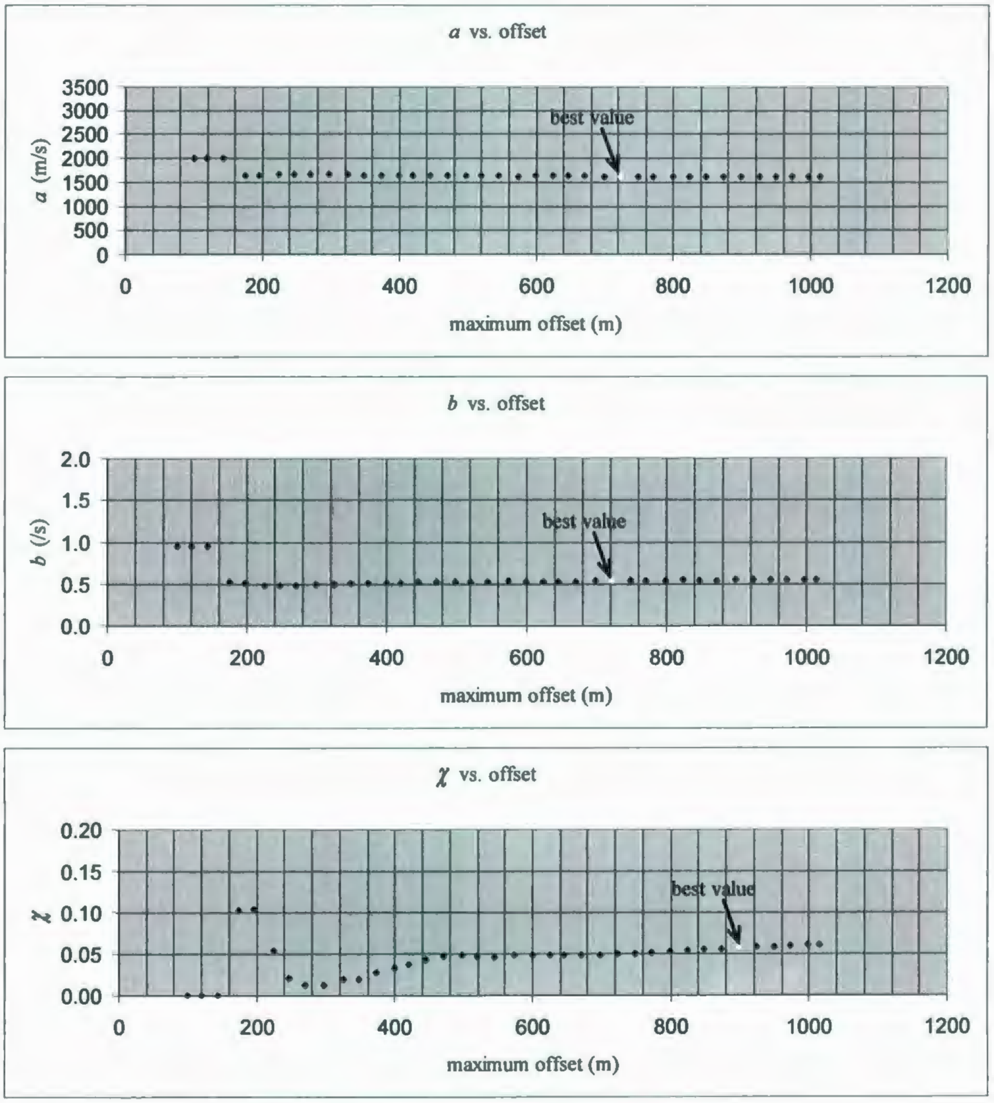


Figure 5.10: Display of results (from Table E.9) of *a*, *b*, and χ, with maximum offsets increasing from 99.6 m to 1014.1 m, for all receivers, for the shortside only, (B). Best values (minimum standard error) are as indicated.

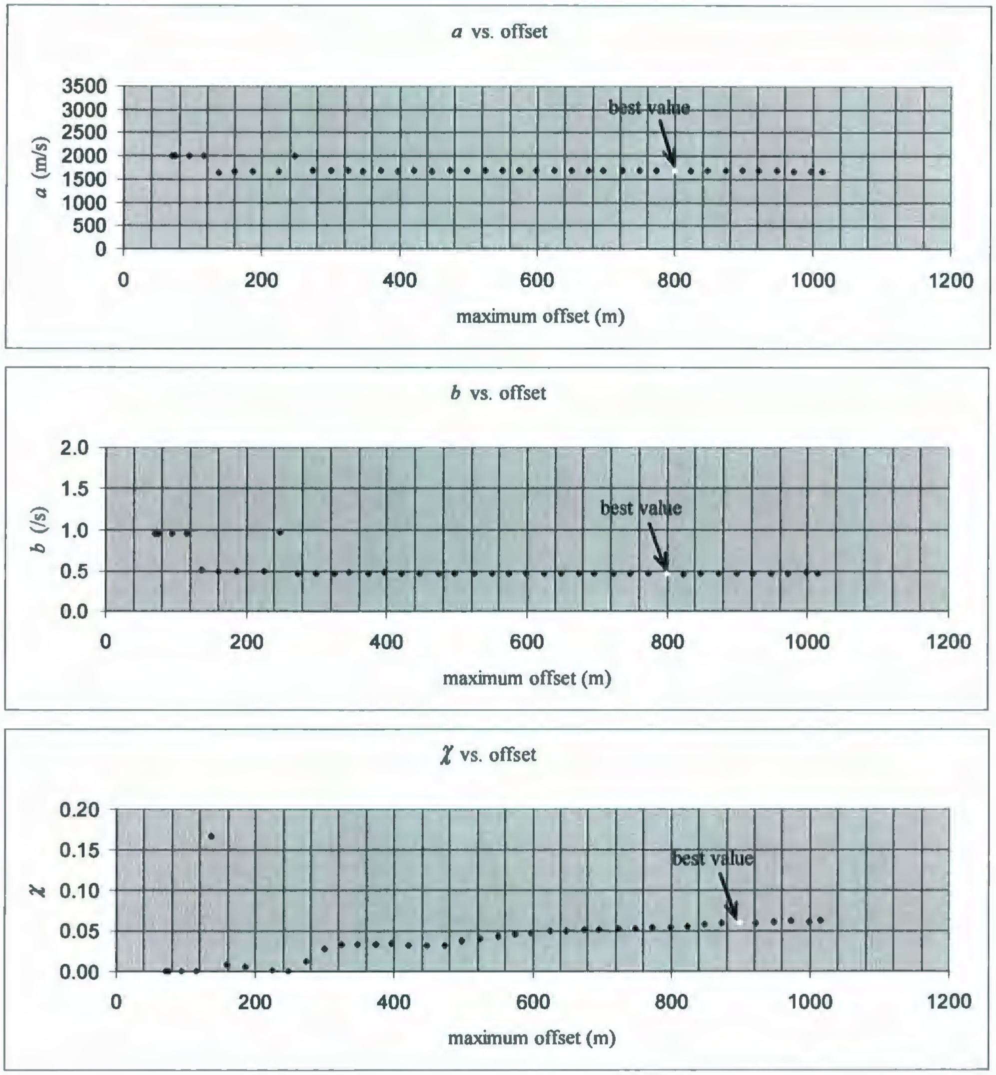


Figure 5.11: Display of results (from Table E.10) of a, b, and χ, with maximum offsets increasing from 69.7 m to 1014.4 m, for all receivers, for the longside, shortoffsets only, (B'). This is the same as Figure 5.8 up to the offset of 1014.4 m, and is included here for comparison with results for the shortside only (B), Figure 5.10. Best values (minimum standard error) are as indicated.

CHAPTER 6: DISCUSSION

6.1 Walkaround VSP - Evaluation of Azimuthal Anisotropy and Other Factors

The walkaround VSP served several purposes. It showed that there is little azimuthal variation in traveltimes after geometry corrections are applied, as can be seen from Figure 3.2b. We concluded that transverse isotropy can be considered as a model.

We infer that any dip or tilt effect is minimal. The medium can thus be considered to be vertically transversely isotropic (VTI). Having accepted such a model of the medium, one can proceed with quantification of the VTI anisotropy parameters by acquisition of a walkaway VSP.

The data quality in the region is good in nearly any direction and for an offset of up to 1.5 km, as can be seen from Figures 2.6 and 3.1. Few offset-VSP data sets existed in the region, and they were of poor quality. Thus, it was important to establish the quality of data expected before embarking on the acquisition of far-offset data.

Another purpose of the walkaround VSP was to address and resolve any operational issues. Walkaway VSPs are considerably more costly and require more resources than other types of data acquired in a well. Doing the walkaround VSP set the stage for the successful acquisition, both technically and operationally, of the walkaway VSP.

6.2 Synthetic Data - Forward Modelling

Synthetic data were used to establish that the program was working as expected and to get familiarized with its limitations. Chart 5.1 summarizes the inputs to the forward modelling and the inverse results obtained.

6.2.1 Fit and Residuals

As a means of evaluating the results, traveltimes computed can be compared to the traveltimes observed. A quantitative fit is obtained by examining the residuals, i.e., the difference between the computed traveltimes and the actual traveltimes. Examining the residuals allows for a better determination of the accuracy of the data. For ideal values of a, b and χ, the residuals should all be zero.

6.2.2 Initial Guesses

Working with the synthetic data, it was realized that the program was sensitive to the initial guess; in particular for χ. Sensitivities to initial guesses for a, b and χ were examined. Since χ was the most sensitive of the three parameters, only results for χ are shown and discussed in Section 5.2.3 and 5.2.4. Default program parameters were not suitable for all situations, for example; if χ was very small or very large. In such situations, the program had computational problems.

6.2.3 Zero Offset

The zero-offset, which is a vertical-incidence case is an isotropic situation, and requires only two parameters, since there is no horizontal velocity component. The forward model assumed a linearly increasing velocity with depth in the medium, where $v = a + bz$. Using this synthetic data for the determination of a and b gave the correct values, confirming the algorithm could be applied to zero-offset data as discussed in Sections 5.2.1 and 5.2.2. Using real data (see Section 5.3.1), values obtained, $a = 1592.27$ m/s and $b = 0.576$ /s, appear reasonable. Using these values, traveltimes were computed and compared to actual traveltimes as shown in Table 6.1 and Figure 6.1. In the zero-offset case, since we only have the vertical component of the velocity, determining χ is impossible.

The modelled traveltimes, using the inverse parameters for *a* and *b*, are satisfactory. However, the residuals in Figure 6.1 show that at shallow depths the discrepancy is significant. This is possibly due to the zero-offset assumption not being valid for shallow depths, i.e., the source is significantly offset relative to depth, and so the actual path deviates significantly from vertical and may be subject to a lateral variation in velocity. Also, the first depth point used is at the sea bed (130.8 m depth) and the arrival time is computed from setting the velocity of water (1524 m/s). This point is atypical of the rest of the medium where velocities are higher and thus may introduce a small error at shallow depths. At depths below 1800 m there seems to be a trend of the residuals becoming more positive. Interval velocities computed from the depths and traveltimes, Table 6.2 and Figure 6.2, show the velocity to be increasing slightly more rapidly than our assumption that velocity increases linearly with depth, and on which the travel-time formula is based, thus giving rise to the pattern of residuals observed.

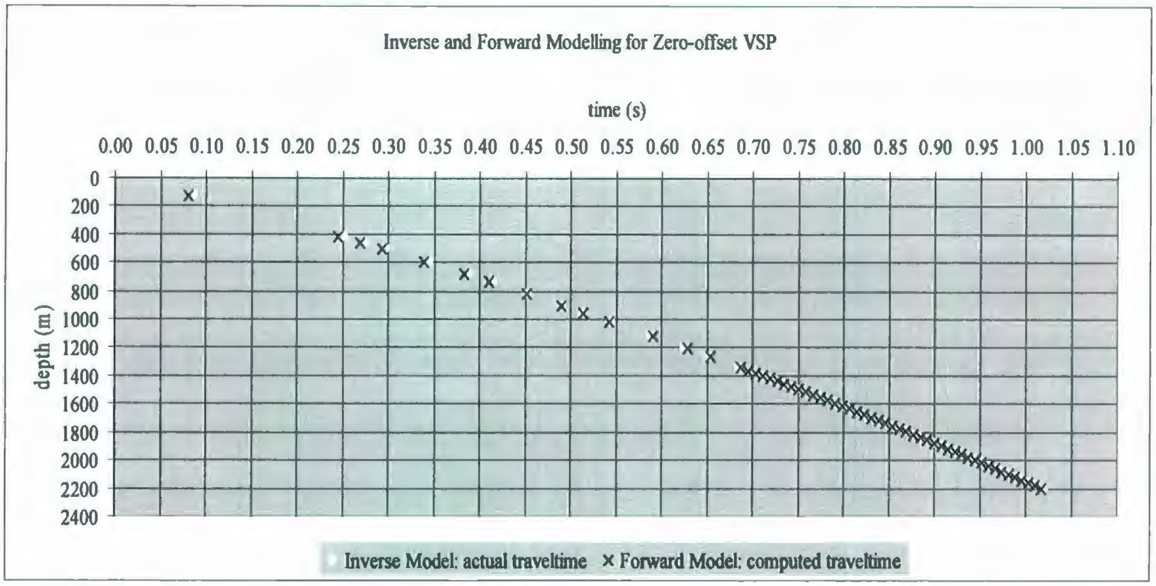
There is a fair amount of scatter in the interval velocities, with the interval velocity increasing or decreasing rapidly. This is a result of the depth sampling being too fine relative to the observed traveltime. By taking coarser sampling (larger depth intervals) the velocities would have less scatter. This scatter may influence the regression analyses. Overall, however, the results of the inverse modelling are good with most of the residuals at ±3 ms.

Table 6.1: Actual traveltimes and forward modelled traveltimes for the zero-offset VSP. Traveltimes are displayed in Figure 6.1 for comparison. Depths are referenced from mean sea level. The sea floor is at a depth of 130.8 m.

Vertical Depth z (m)	Vertical Travel Time (s)	Travel Times from Forward Modelling (s)	Residual (s)	Vertical Depth z (m)	Vertical Travel Time (s)	Travel Times from Forward Modelling (s)	Residual (s)
130.80	0.08583	0.08026	0.00556	1635.40	0.80507	0.80698	-0.00191
418.60	0.25169	0.24481	0.00688	1655.50	0.81313	0.81490	-0.00177
463.10	0.27517	0.26892	0.00625	1675.60	0.82052	0.82278	-0.00226
507.40	0.29794	0.29259	0.00535	1695.90	0.82767	0.83070	-0.00303
595.10	0.34494	0.33852	0.00642	1716.10	0.83564	0.83855	-0.00291
681.50	0.38807	0.38261	0.00546	1736.20	0.84338	0.84632	-0.00295
738.10	0.41464	0.41090	0.00373	1756.40	0.85203	0.85410	-0.00207
820.90	0.45313	0.45148	0.00165	1776.40	0.85982	0.86177	-0.00194
901.30	0.49119	0.48999	0.00121	1796.60	0.86757	0.86947	-0.00190
953.00	0.51432	0.51431	0.00002	1816.90	0.87594	0.87719	-0.00125
1014.70	0.54442	0.54289	0.00153	1837.10	0.88448	0.88483	-0.00035
1119.90	0.58904	0.59057	-0.00153	1857.30	0.89212	0.89243	-0.00031
1205.00	0.62524	0.62821	-0.00297	1877.60	0.89973	0.90005	-0.00032
1264.00	0.65182	0.65383	-0.00201	1897.80	0.90789	0.90759	0.00030
1343.40	0.68524	0.68772	-0.00248	1917.80	0.91504	0.91502	0.00001
1362.80	0.69441	0.69591	-0.00150	1938.00	0.92258	0.92250	0.00009
1381.90	0.70222	0.70393	-0.00171	1958.10	0.93072	0.92991	0.00081
1400.90	0.70976	0.71187	-0.00211	1977.90	0.93803	0.93717	0.00086
1419.60	0.71764	0.71964	-0.00201	1997.70	0.94579	0.94441	0.00138
1438.10	0.72494	0.72731	-0.00237	2017.90	0.95314	0.95176	0.00138
1456.60	0.73341	0.73493	-0.00152	2038.50	0.96149	0.95923	0.00226
1475.20	0.74042	0.74257	-0.00215	2059.20	0.96963	0.96669	0.00293
1494.20	0.74806	0.75034	-0.00227	2079.80	0.97683	0.97410	0.00273
1513.90	0.75584	0.75835	-0.00251	2100.30	0.98409	0.98143	0.00266
1534.10	0.76486	0.76653	-0.00168	2120.80	0.99164	0.98873	0.00290
1554.60	0.77372	0.77479	-0.00107	2141.20	0.99939	0.99597	0.00342
1574.90	0.78132	0.78294	-0.00161	2161.50	1.00642	1.00314	0.00328
1595.10	0.78957	0.79100	-0.00143	2181.80	1.01363	1.01029	0.00334
1615.20	0.79704	0.79899	-0.00195	2202.00	1.02068	1.01736	0.00332
$a =$ 1592.25865118521 m/s							
$b =$ 0.575514064006845 /s							

Table 6.2: Average and interval velocities for the zero-offset VSP. Velocities are displayed in Figure 6.2 for comparison. Depths are referenced from mean sea level. The sea floor is at a depth of 130.8 m, the velocity of water is 1524 m/s.

Vertical depth (m)	Average velocity (m/s)	Interval velocity (m/s)	Vertical depth (m)	Average velocity (m/s)	Interval velocity (m/s)
130.80	1524.00	1524.00	1635.40	2031.38	2514.68
418.60	1663.17	1735.19	1655.50	2035.97	2495.18
463.10	1682.95	1894.92	1675.60	2042.12	2717.52
507.40	1703.05	1945.93	1695.90	2049.01	2841.10
595.10	1725.21	1865.70	1716.10	2053.64	2534.51
681.50	1756.12	2003.29	1736.20	2058.63	2596.86
738.10	1780.12	2130.76	1756.40	2061.43	2335.00
820.90	1811.63	2151.04	1776.40	2066.01	2565.79
901.30	1834.92	2112.25	1796.60	2070.83	2606.41
953.00	1852.92	2235.11	1816.90	2074.24	2427.09
1014.70	1863.82	2050.03	1837.10	2077.05	2365.11
1119.90	1901.24	2357.85	1857.30	2081.89	2641.73
1205.00	1927.26	2350.67	1877.60	2086.86	2670.66
1264.00	1939.20	2219.96	1897.80	2090.35	2475.48
1343.40	1960.47	2375.35	1917.80	2095.87	2796.57
1362.80	1962.53	2116.23	1938.00	2100.62	2676.58
1381.90	1967.90	2445.60	1958.10	2103.86	2471.49
1400.90	1973.78	2521.19	1977.90	2108.56	2706.50
1419.60	1978.16	2373.00	1997.70	2112.20	2552.25
1438.10	1983.75	2533.24	2017.90	2117.11	2749.51
1456.60	1986.06	2183.78	2038.50	2120.15	2466.83
1475.20	1992.39	2654.73	2059.20	2123.70	2542.64
1494.20	1997.43	2485.96	2079.80	2129.14	2861.52
1513.90	2002.95	2533.33	2100.30	2134.25	2821.07
1534.10	2005.74	2239.72	2120.80	2138.69	2718.02
1554.60	2009.25	2312.11	2141.20	2142.51	2632.48
1574.90	2015.68	2670.84	2161.50	2147.70	2884.64
1595.10	2020.22	2449.99	2181.80	2152.47	2818.83
1615.20	2026.51	2691.06	2202.00	2157.38	2863.17



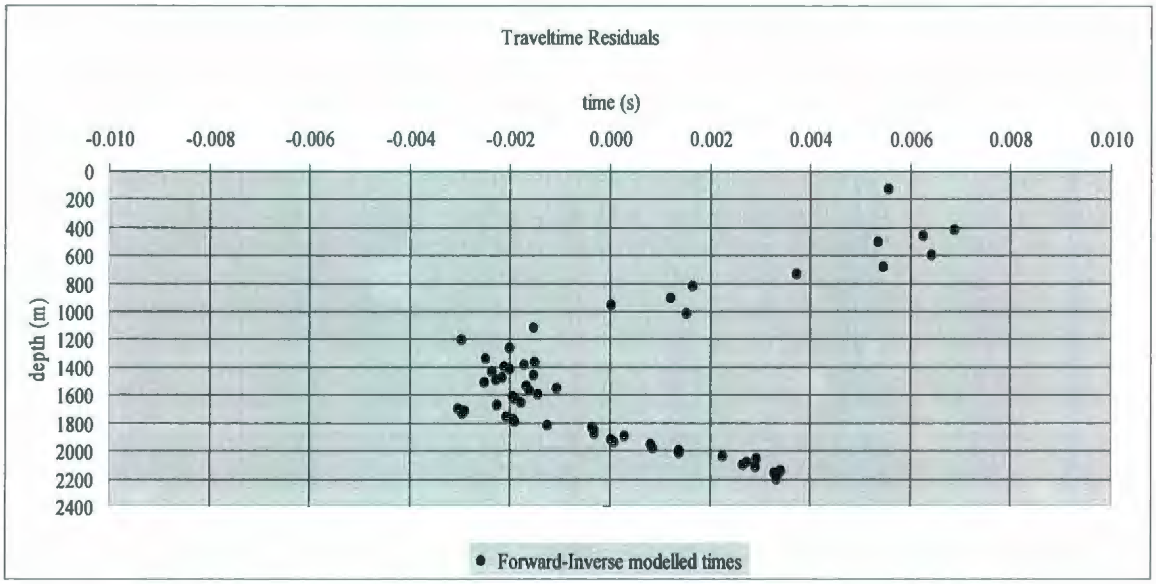
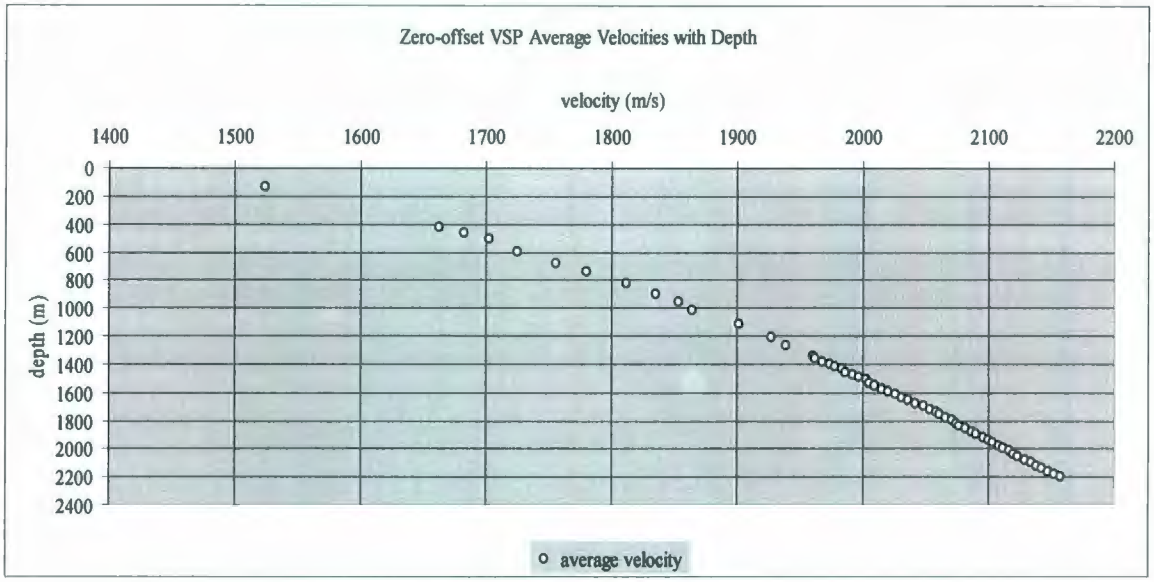


Figure 6.1: Actual traveltimes vs. forward modelled traveltimes for the zero-offset VSP (above) and residuals (below). At very shallow depths the discrepancy seen from the residuals is possibly due to oblique rays. Results of the inverse modelling are good; most of the residuals are within ±3 ms.



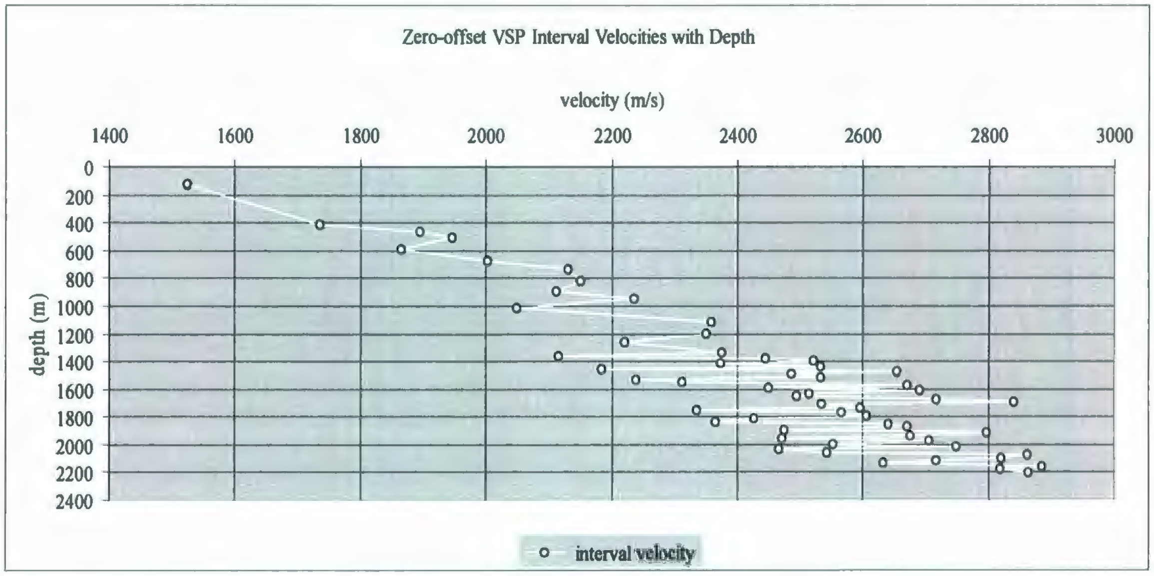


Figure 6.2: Average (top) and interval (below) velocities for the zero-offset VSP. The scatter in the interval velocities may be because of the depth sampling being too fine relative to the observed traveltime. By taking coarser or larger depth intervals, the velocities would appear to have less scatter.

6.2.4 Offset

Using the values obtained for *a* and *b* from the zero-offset VSP, discussed above and shown in Table 5.5, traveltimes were modelled for the same offsets and depths as the offset-VSP data. Traveltimes versus offset for the isotropic case were thus obtained. Tables F.1a and F1b and Figures 6.3a and 6.3b depict the results of the forward modelling and the observed times for receivers at depths 1974 m and 2014 m. The difference in the actual observed traveltimes and the modelled traveltimes, or residuals, can be considered due to anisotropy or lateral inhomogeneity. For the receiver at depth 1974 m, scatter can be seen at offsets greater than 3400 m. This is likely due to rays that are near horizontal or from refracted arrivals.

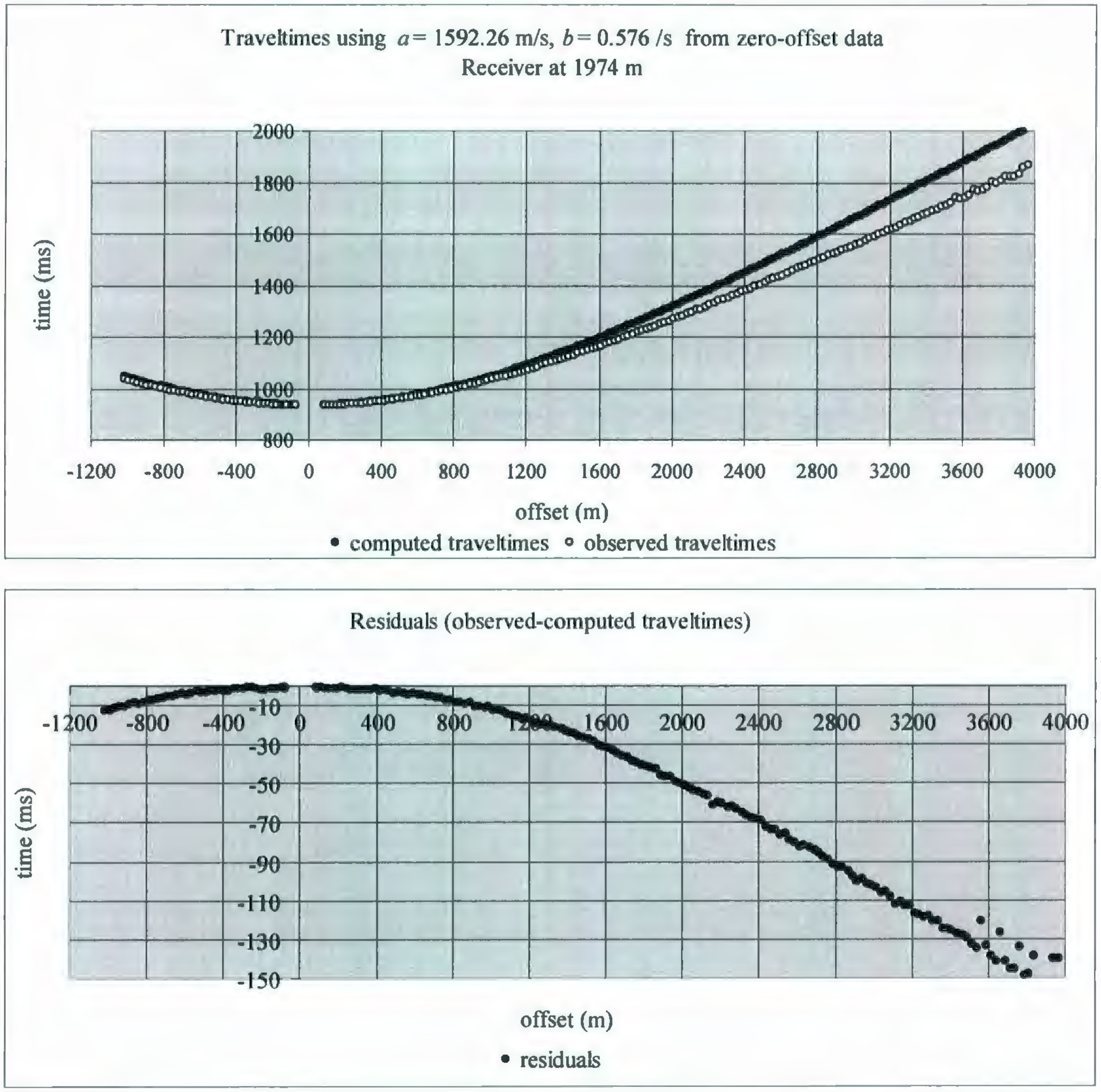
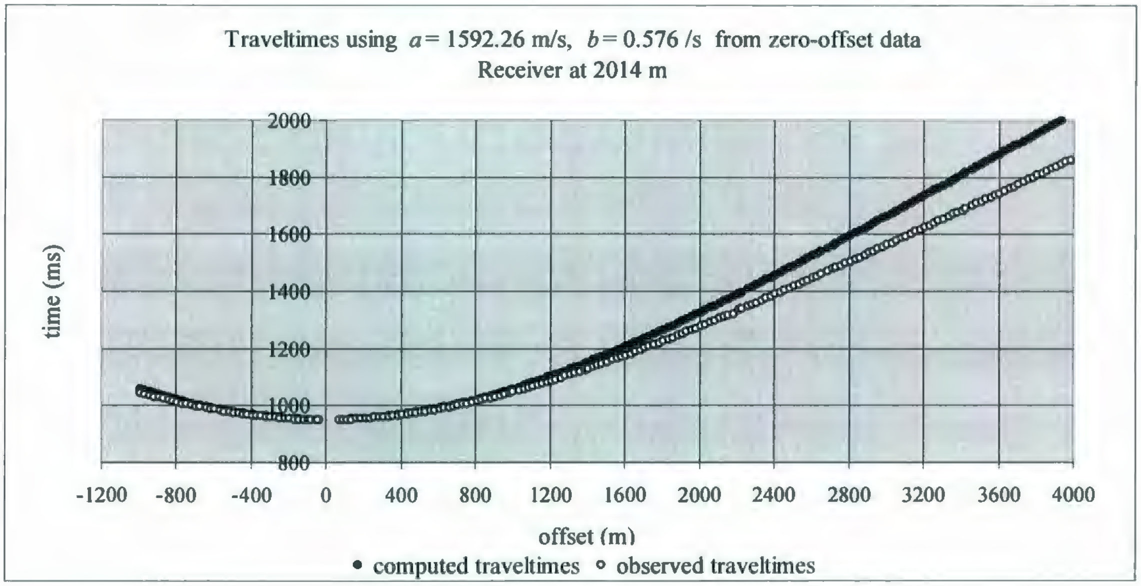


Figure 6.3a: Isotropy vs. anisotropy, forward modelling with isotropic parameters for receiver at 1974 m depth. The difference between the observed traveltimes and modelled traveltimes, the residual, shows the possible effect of anisotropy.



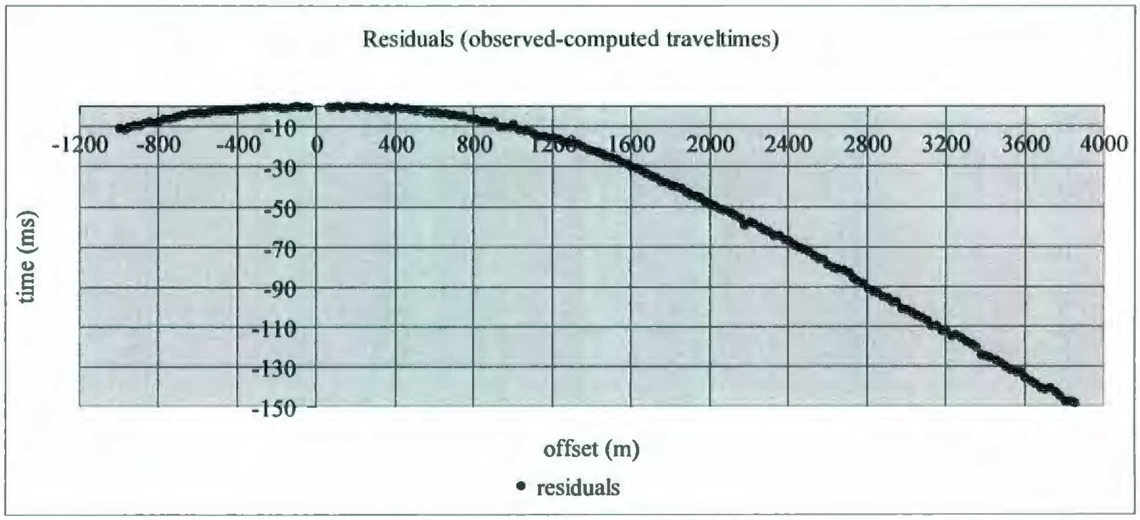


Figure 6.3b: Isotropy vs. anisotropy, forward modelling with isotropic parameters for receiver at 2014 m depth. The difference between the observed traveltimes and modelled traveltimes, the residual, shows the possible effect of anisotropy.

6.2.4.1 Traveltime Picks

The traveltime picks are a source of error. Traveltimes were obtained from the VSP data, by picking the 'first-break'. This is where the first deflection is observed on a trace and is considered to be the direct arrival time of the P wave.

Figure 3.3 shows the walkaway VSP data used. As can be seen, the data are generally of good quality - 'clean'. With increasing offset, two effects are observed. The signal-to-noise ratio decreases, and the seismic wavelet exhibits stretching due to frequency dispersion, i.e., higher frequencies are attenuated or absorbed faster than lower frequencies, causing the wavelet to broaden. Hooke's law of elasticity, for a linearly elastic continuum, assumes no attenuation or dispersion. In an idealized material described by Hooke's Law, the signal would propagate unaffected through the medium. However, in practice we always deal with limitations as observed here. Thus, the picking of first arrivals becomes less reliable with increasing offset. Figure 6.4 shows some far-offset traces compared to near-offset traces to illustrate the picking difficulty at the far offset. This may be the cause of some of the scatter observed in the residuals at the far offsets.

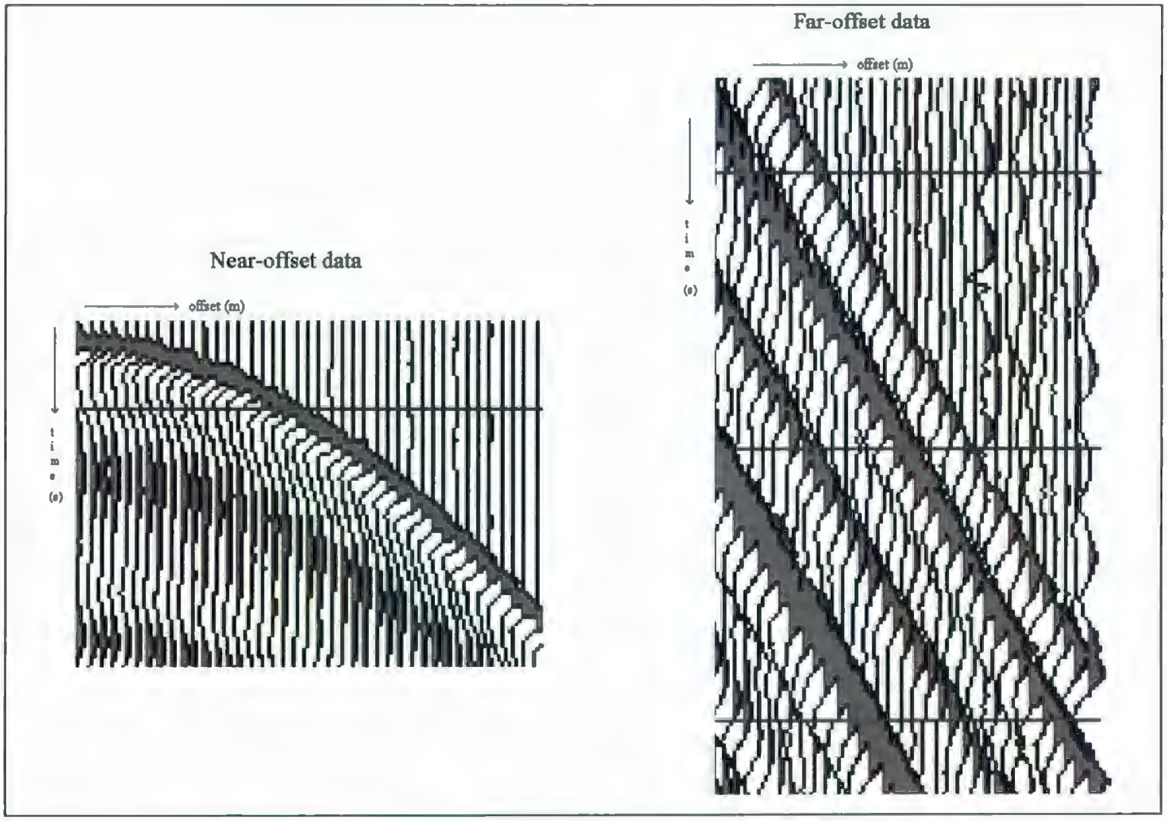


Figure 6.4: Near- and far-offset VSP data. With increasing offset, the background noise level increases and the seismic wavelet broadens due to frequency dispersion. Thus, picking of first arrivals is less reliable with offset.

6.3 Real data – Inverse Modelling

6.3.1 Dip Considerations

From observations on seismic data and an understanding of the regional geology of the area, a mild dip of approximately 2° was estimated in the acquisition direction of the walkaway line. The effect of the dip can be assessed by examining the traveltimes in opposite directions. Figure 6.5 shows the traveltimes observed for longside shortoffsets (B') vs. shortside (B) for receivers at depth 1974 m and 2014 m, respectively. Only a slight difference in traveltimes can be seen.

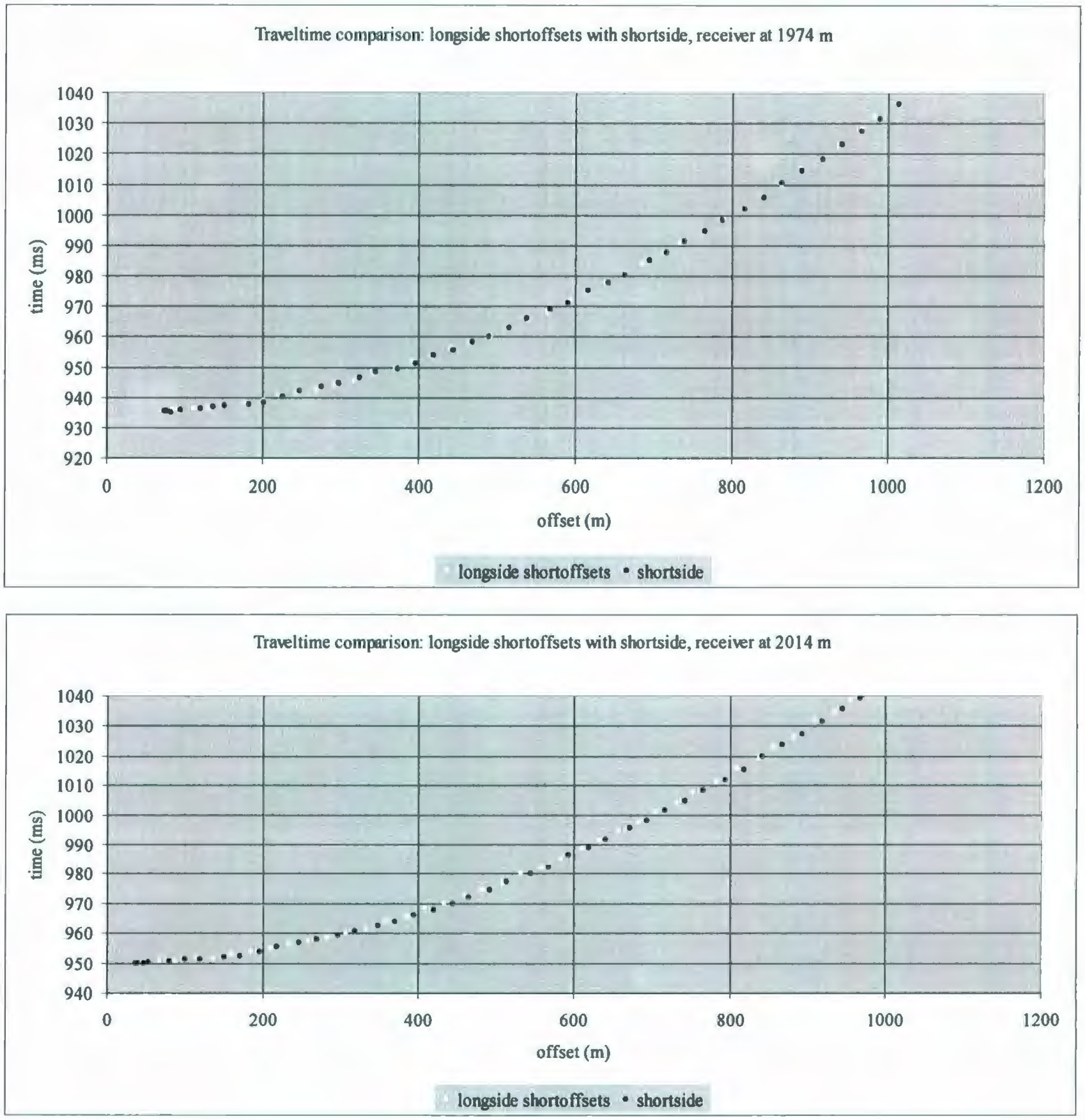


Figure 6.5: Dip considerations. Traveltimes for longside shortoffsets (B') vs. shortside (B). Only a slight difference in traveltimes is observed due to the regional dip of 2° estimated in the area.

Figure 6.6 combines Figures 5.5 and 5.6, the results as obtained for *a* and *b* only, with $\chi = 0$, for the shortside (B) and the longside shortoffsets (B'). Values obtained show a small difference between the two sides.

Figure 6.7 combines, for comparison, the results obtained for *a*, *b* and χ shown in Figures 5.10 and 5.11, i.e., shortside (B) with longside shortoffsets (B'). As above, values obtained show a small difference between the two sides. The scatter observed in the values of χ are at near offsets, where the offsets may not be sufficiently long to be able to adequately discriminate between horizontal and vertical velocities.

The traveltime difference is small, but sufficient to affect the values obtained for *a*, *b* and χ for the three-parameter case and also *a*, and *b* for the two-parameter case. It would seem, therefore, appropriate, to only consider data from the longside (A+C) for the estimations of *a*, *b* and χ.

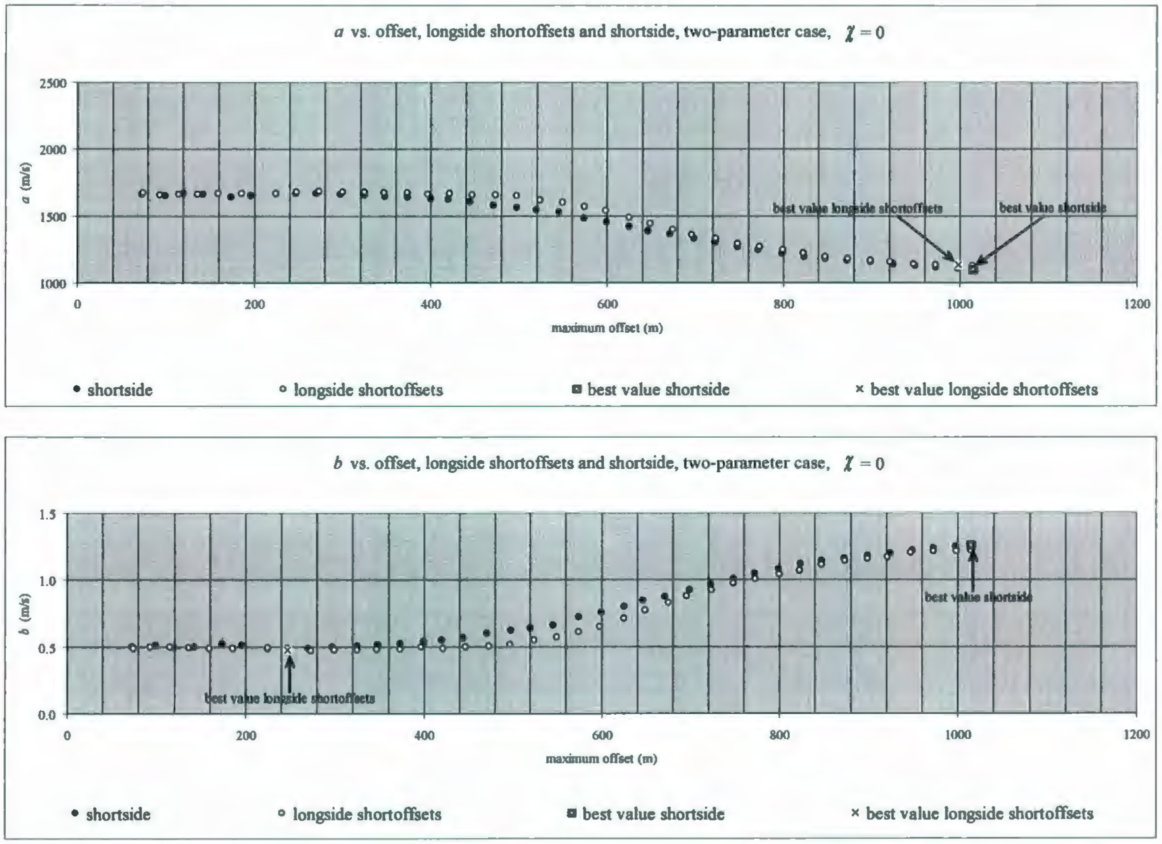


Figure 6.6: Comparison of a and b, $\chi = 0$, obtained for longside shortoffsets (B') with shortside (B). Values obtained show a small difference between the two sides.

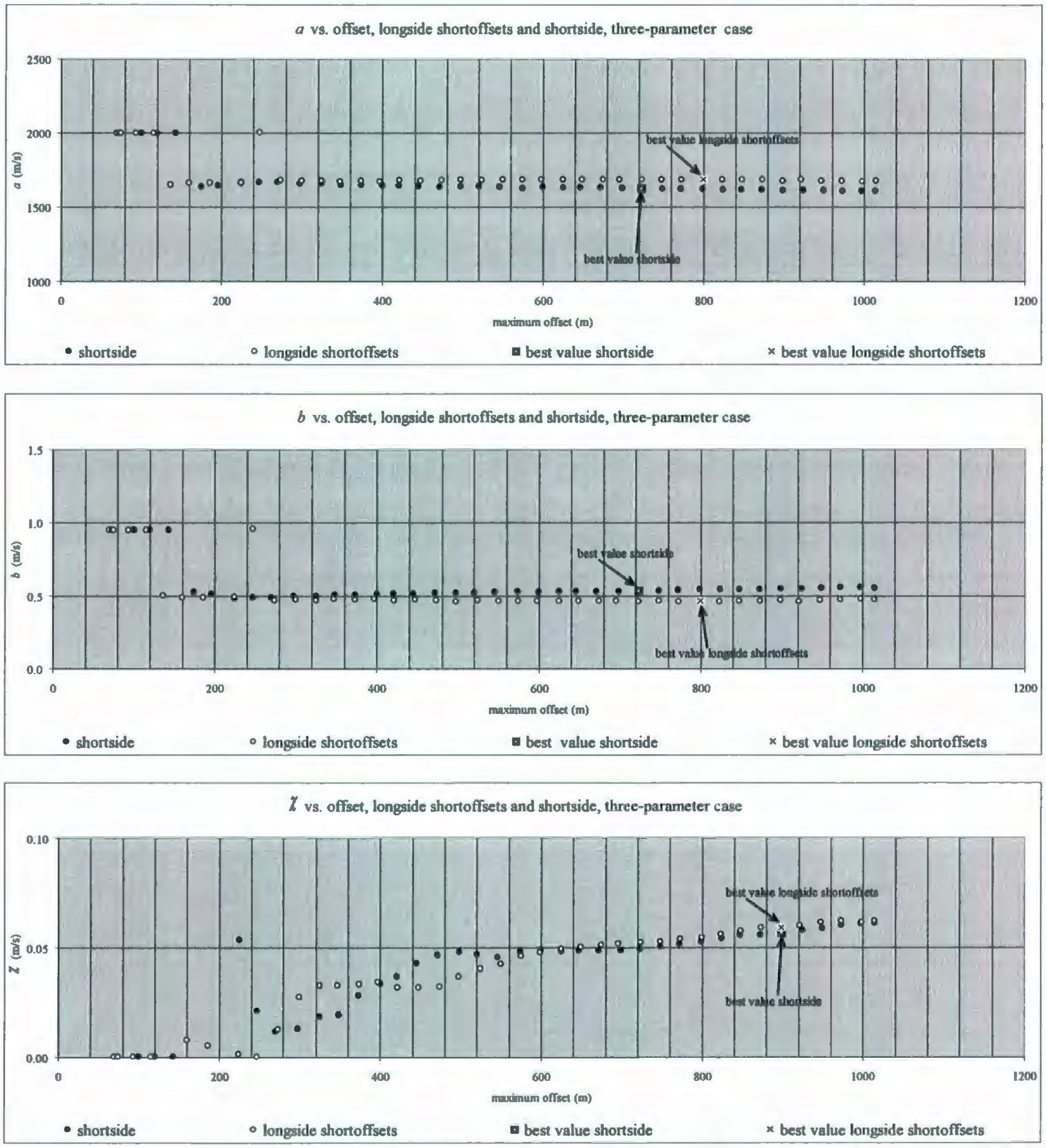


Figure 6.7: Comparison of a, b and χ obtained for longside shortoffsets (B') with shortside (B). Values obtained show a small difference between the two sides. Scatter observed in the values of χ are at offsets which may not be sufficiently long for discrimination between horizontal and vertical velocities.

6.3.2 Two-parameter Case (Inhomogeneous Isotropic), $\chi = 0$, Longside

For the offset data, setting $\chi = 0$, implies the medium is inhomogeneous, but isotropic. This means that we are looking for a solution that does not consider anisotropy and can be defined by the two parameters *a* and *b*. Figure 5.3 and Table E.2 show the results for *a* and *b* with $\chi = 0$ for the longside (A+C). The results can be viewed as four segments: (a) offsets less than 500 m, where *a* and *b* are nearly constant with $a \approx 1600$ m/s and $b \approx 0.5$ /s, (b) from about 500 m to about 1000 m, where *a* decreases and *b* increases, (c) from about 1000 m to about 2600 m, where *a* and *b* stay relatively constant at $a \approx 1100$ m/s and $b \approx 1.3$ /s, and (d) from about 2600 m to about 4000 m, where *a* increases and *b* decreases.

In order to evaluate which segment provides the best estimated combination of *a* and *b*, we compare the traveltimes and residuals obtained from representative values for *a* and *b* from each segment, see Figure 6.8a and Figure 6.8b, and Tables F.2a to F.5b, for receivers at 1974 m and 2014 m, respectively. The curve for segment 3, in both cases, shows the smallest residuals. The residuals vary close to zero (|residuals| < 10 ms) up to offsets of about 3000 m. From offset data then, the isotropic 'best' solution is $a =$ 1131.62 m/s and $b = 1.22$ /s. The fit with these parameters to the observed data is good up to 3000 m, as expected, since this is the value obtained by inversion at an offset of 2773.23 m (see Table E.2).

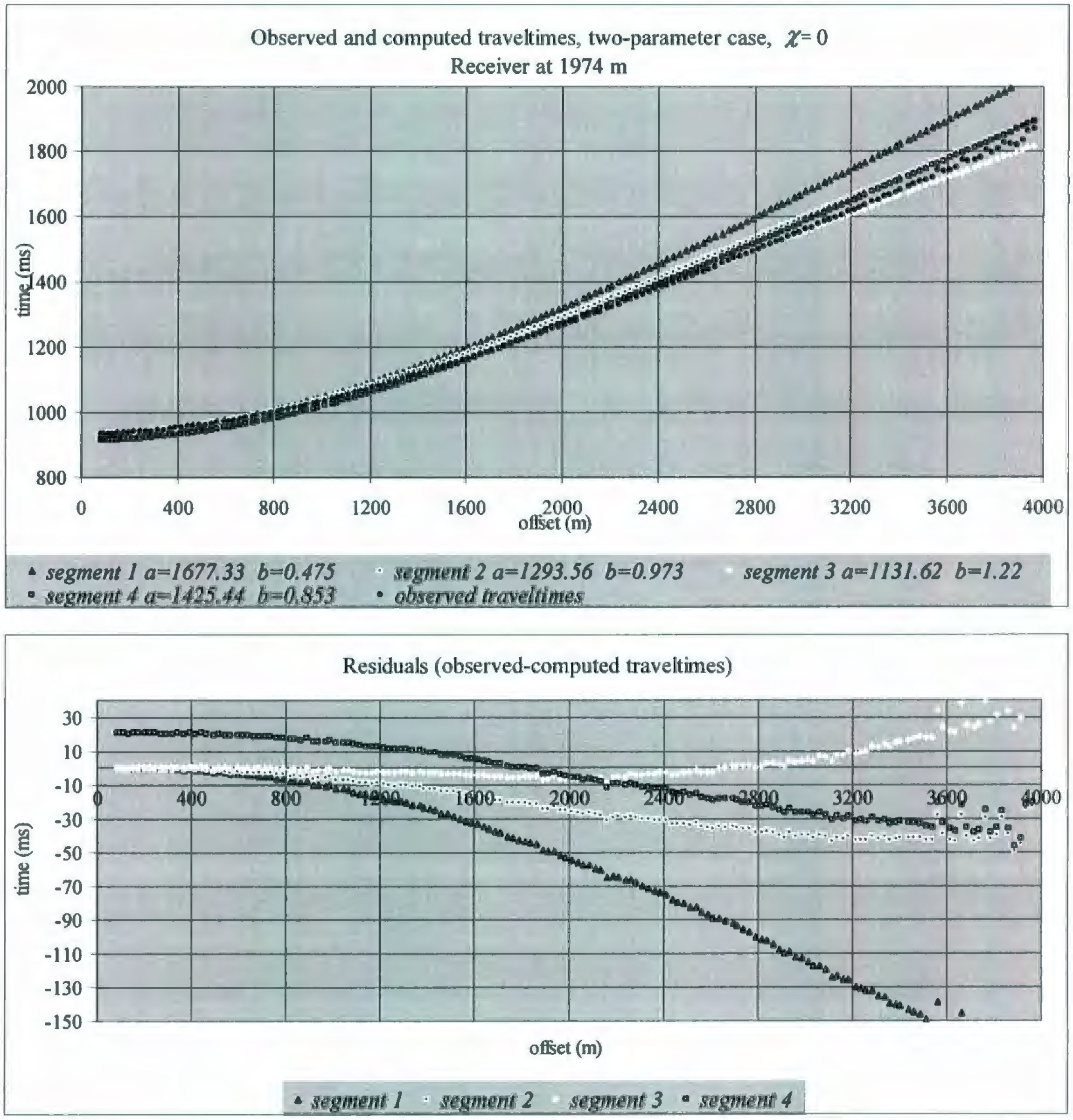


Figure 6.8a: Comparison of traveltimes and residuals from four segments of the inverse results obtained for the 'longside' with receiver at 1974 m. The curve for segment 3 shows the least amount or best residuals. The residuals vary close to zero (|residuals| < 10 ms) up to offsets of about 3000 m. From offset data, the isotropic 'best' solution is a = 1131.62 m/s and b = 1.22 /s.

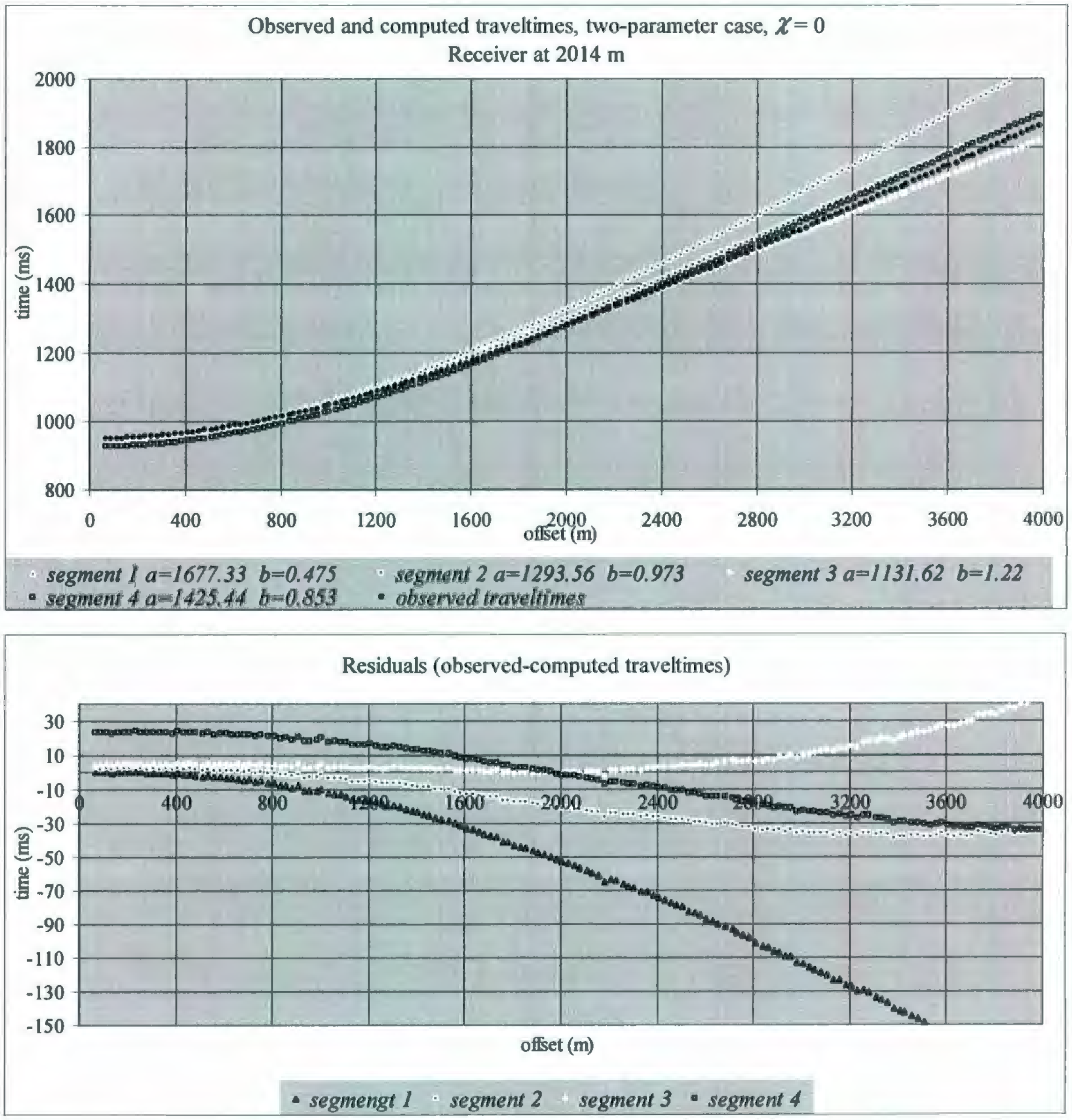


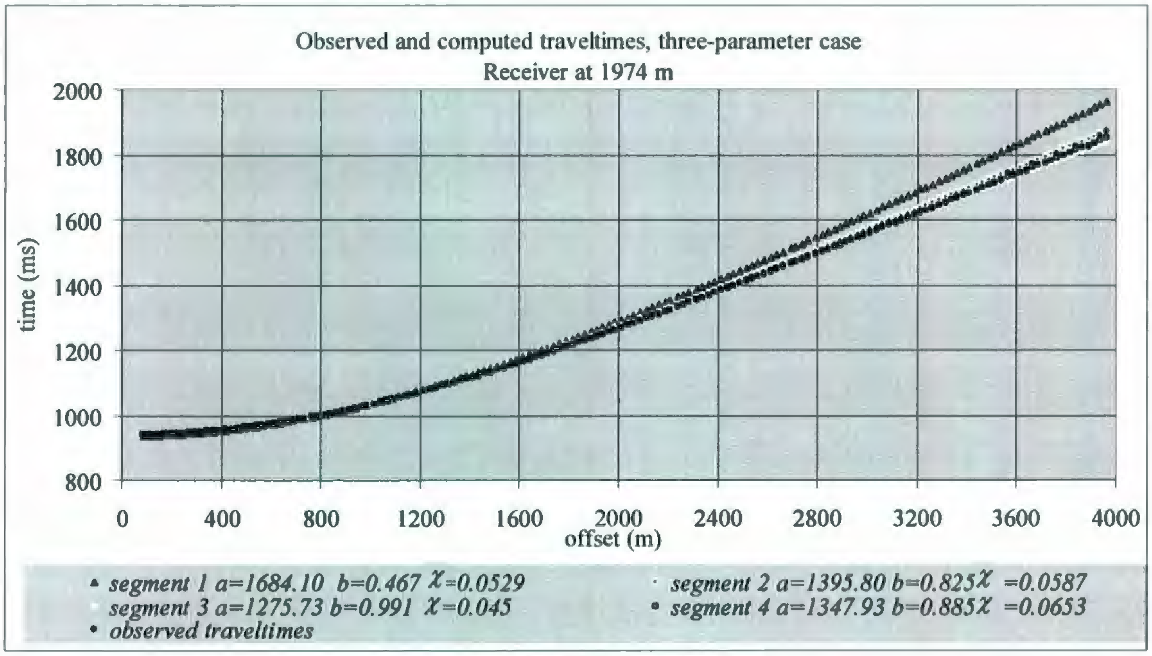
Figure 6.8b: Comparison of traveltimes and residuals from four segments of the inverse results obtained for the 'longside' with receiver at 2014 m. As in Figure 6.8a, the curve for segment 3 shows the smallest residuals.

6.3.3 Three-parameter Case (Inhomogeneous Anisotropic), Longside

Figure 5.8 shows the results obtained for a, b and χ with $\chi \neq 0$, longside (A+C). Again, four segments can be seen: (a) up to about1500 m, where a and b are nearly constant with $a \approx 1600$ m/s and $b \approx 0.5$ /s and χ increasing to 0.07, (b) from about 1500 m to about 2100 m, where a and χ are decreasing and b is increasing, (c) from about 2100 m to about 3200 m, where $a \approx 1300$ m/s and $b \approx 1.0$ /s and $\chi \approx 0.45$ and there is little change in a, b and χ, and (d) from about 3200 m to about 4000 m, where a and χ increase to ≈ 1500 m/s and 0.11 and b decreases to ≈ 0.675 /s .

For each of these segments we compare the traveltimes and residuals obtained from representative values for a, b and χ from each segment, Figure 6.9a and 6.9b, Tables F.6a to F.9b, for receivers at 1974 m and 2014 m, respectively. This time, the values of a, b and χ from two of the segments, segments 3 and 4 (see Figures 6.9a and 6.9b), give traveltimes with a very good fit to the observed traveltimes, the segment 4 fit being slightly better. The residuals are better than the isotropic solution. They are even closer to zero ($|\text{residuals}| < 5$ ms) than the isotropic residuals, and for offsets up to 3400 m, which is farther than for the isotropic solution.

Figure 6.10 compares the residuals obtained using a and b with those obtained using a, b and χ. The three-parameter case gives a better solution than the two-parameter case. Although the two-parameter solution is comparable up to about 2600 m, the three-parameter solution encompasses farther offsets.



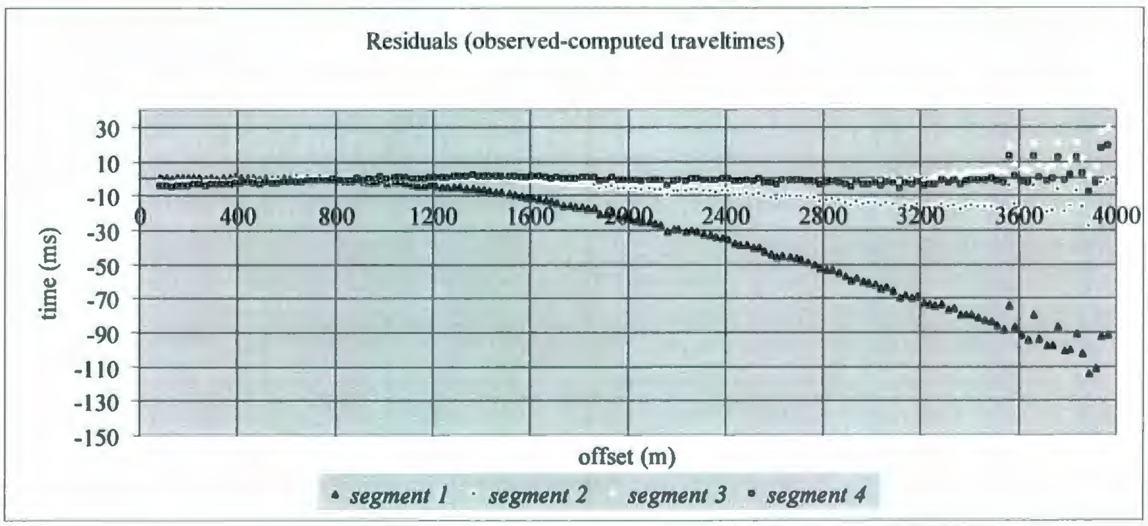
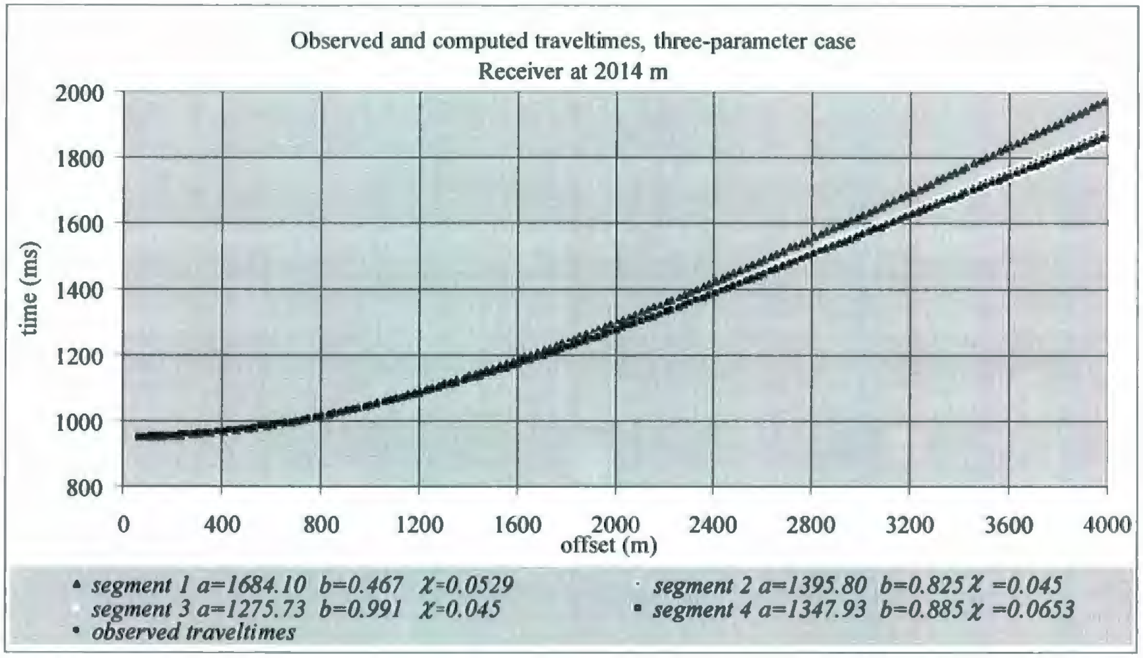


Figure 6.9a: Comparison of traveltimes and residuals from four segments of the inverse results obtained for the 'longside' with receiver at 1974 m. Values of *a*, *b* and χ from segments 3 and 4 give traveltimes with a very good fit to the observed traveltimes. The residuals are better than the isotropic solution (see Figures 6.8a and 6.8b). They are even closer to zero (|residuals| < 5 ms) than the isotropic residuals, and for offsets up to 3400 m, which is farther than for the isotropic solution.



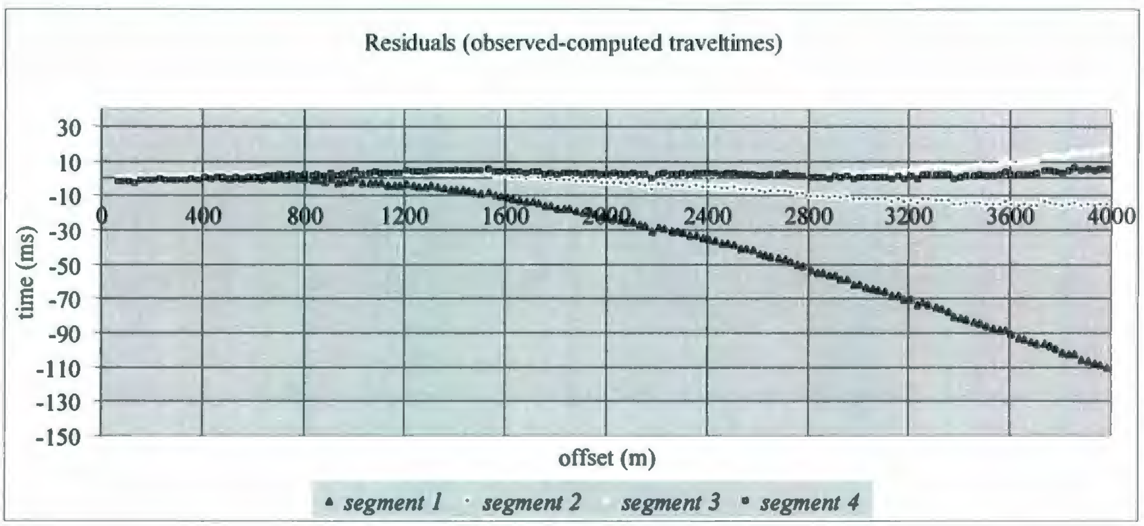


Figure 6.9b: Comparison of traveltimes and residuals from four segments of the inverse results obtained for the 'longside' with receiver at 2014 m. As in Figure 6.9a, the curves for segments 3 and 4 show the least amount or best residuals.

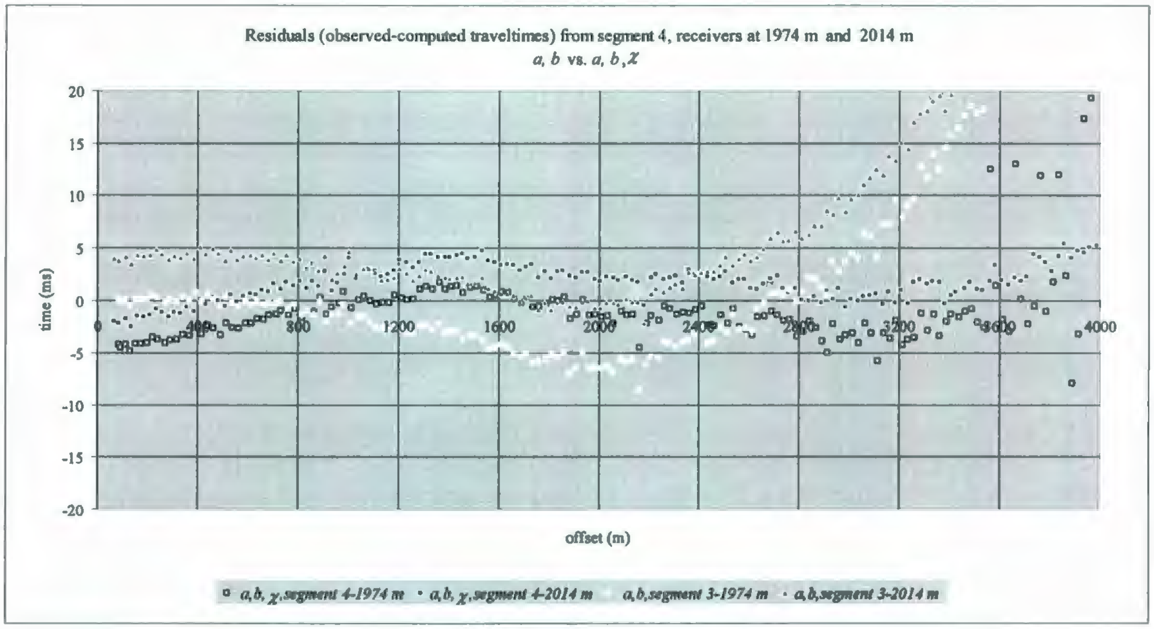


Figure 6.10: Comparison of residuals from two-parameter (isotropic) case vs. three-parameter (anisotropic) case. The two-parameter solution is comparable to the three-parameter solution up to about 2600 m. The three-parameter solution encompasses farther offsets and gives a better solution than the two-parameter case.

6.3.4 Offset Considerations: Longside, Longoffsets

Subtle geological changes in the medium may be the cause of the results appearing in four segments. The $ab\chi$ model does not take into account such heterogeneities. Also contributing to the results appearing in four segments may be the way the regression analysis attempts to find the 'best fit'. For near offsets, the traveltime differential relative to the change in offset between shots is not large enough to be detected. The segment where a decreases and b increases, segment 2, could be considered as a transition zone where the traveltimes are beginning to show variations with offset, but the regression analysis is affected by the input of the near-offset data. For segment 3, the regression analysis has sufficient data points to be less influenced by the near offsets and, thus, may be giving a truer value of the inverse parameters. Segment 4, which includes very far offsets, is unreliable, due to the possible inclusion of near horizontal or upturned rays or even refracted arrivals.

In order to investigate if not using the near-offset range would give more reliable and better estimates of parameters, offsets were limited to the range: 2849.9 m to 3984.4 m. Results obtained are shown in Table E.8 and Figure 5.9 for a, b and $\chi \neq 0$ and Table E.3 and Figure 5.4 for a, b and $\chi = 0$.

For the isotropic case, Figure 5.4, we see that a increases as b decreases correspondingly with offset, for offsets greater than 3000 m, as was observed in this range before in Figure 5.3. For the anisotropic case, a, b and χ stay within a small range of values, i.e., are nearly constant as shown in Figure 5.9.

To see the influence that the near data have, values obtained using all offsets and limiting the offsets, are displayed in Figure 6.11. Using only the limited offset range gives more consistent values of a, b and χ for the interval. We compute the traveltimes and residuals as before for representative values of a, b and χ, and display them for comparison in Figure 6.12.

For the shallow receiver, at 1974 m, the fit using values from the longoffsets only is better (white-dotted curve) than that obtained using all offsets (black-dotted curve), most of the white points lie close to the 0 axis. For the deeper receiver, there is little difference, up to about 3200 m offset and then the white-dotted curve is a better fit, i.e., the longoffsets only again.

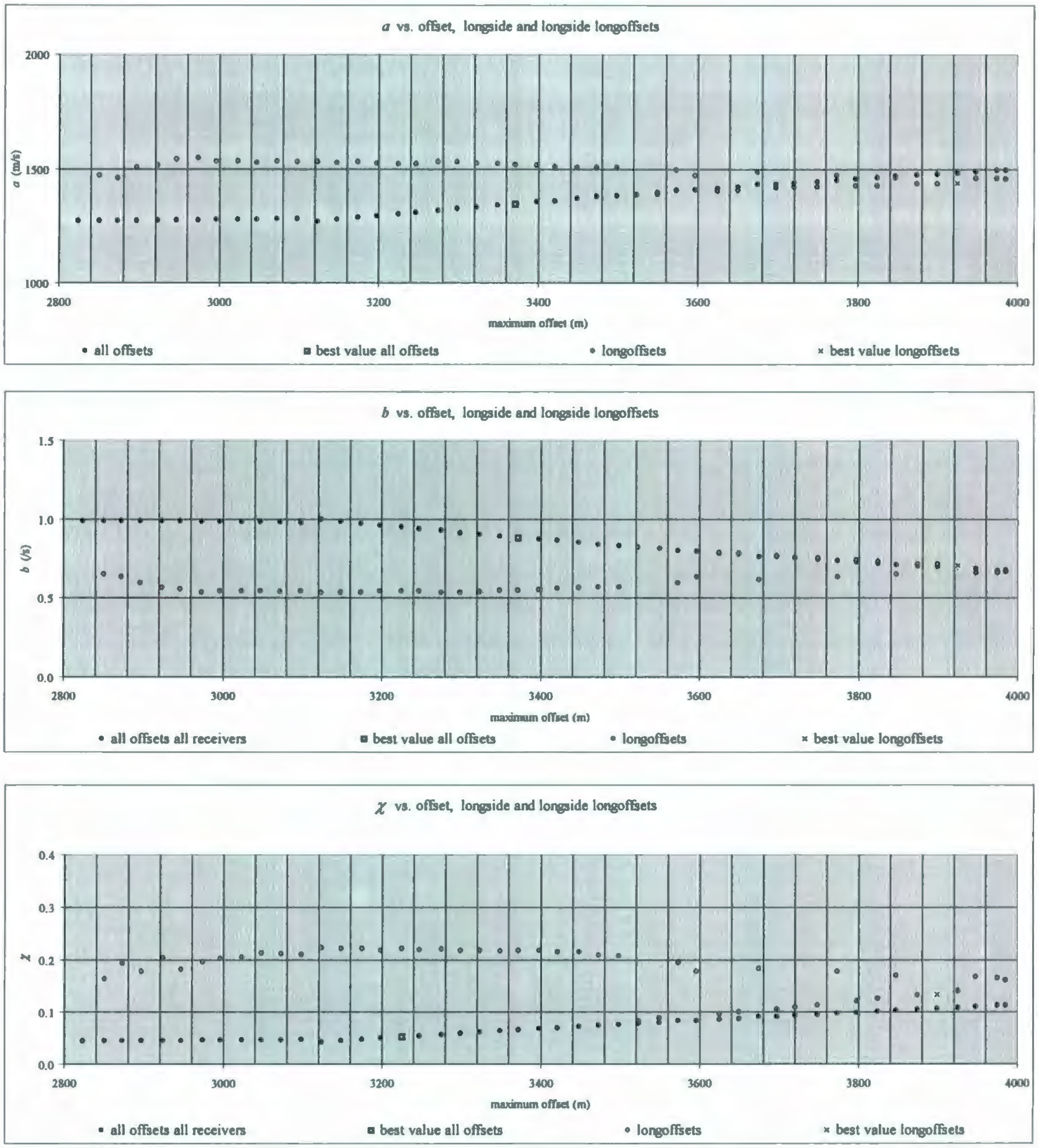
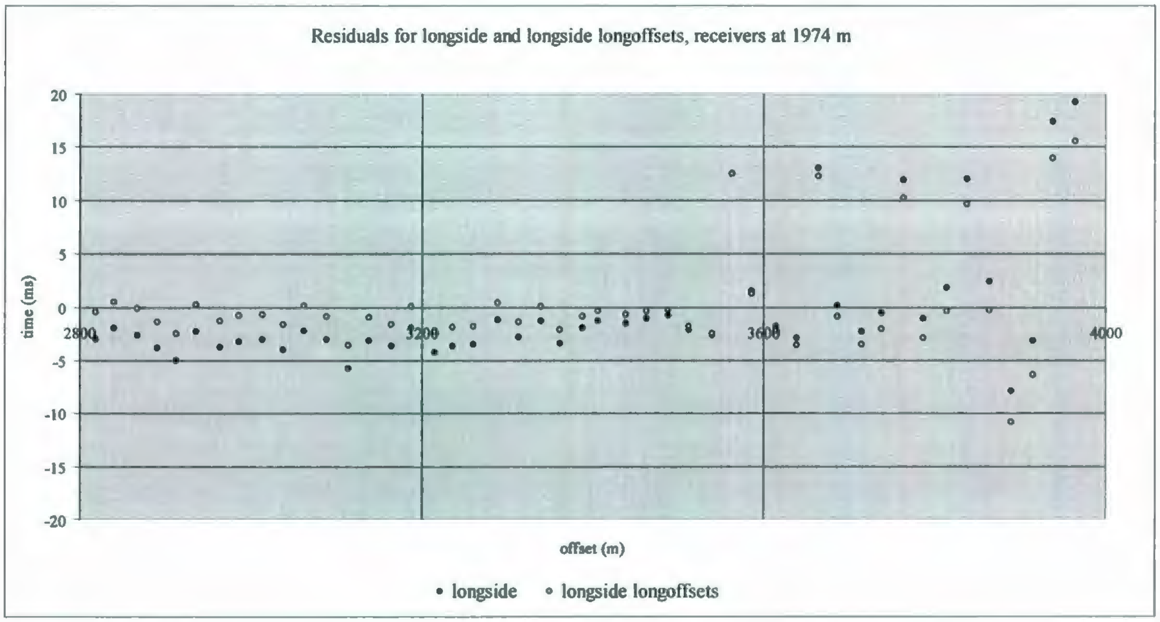


Figure 6.11: Using all offsets vs. limiting the offsets to longoffsets only. Using only the limited offset range more consistent values for a, b and χ are obtained.



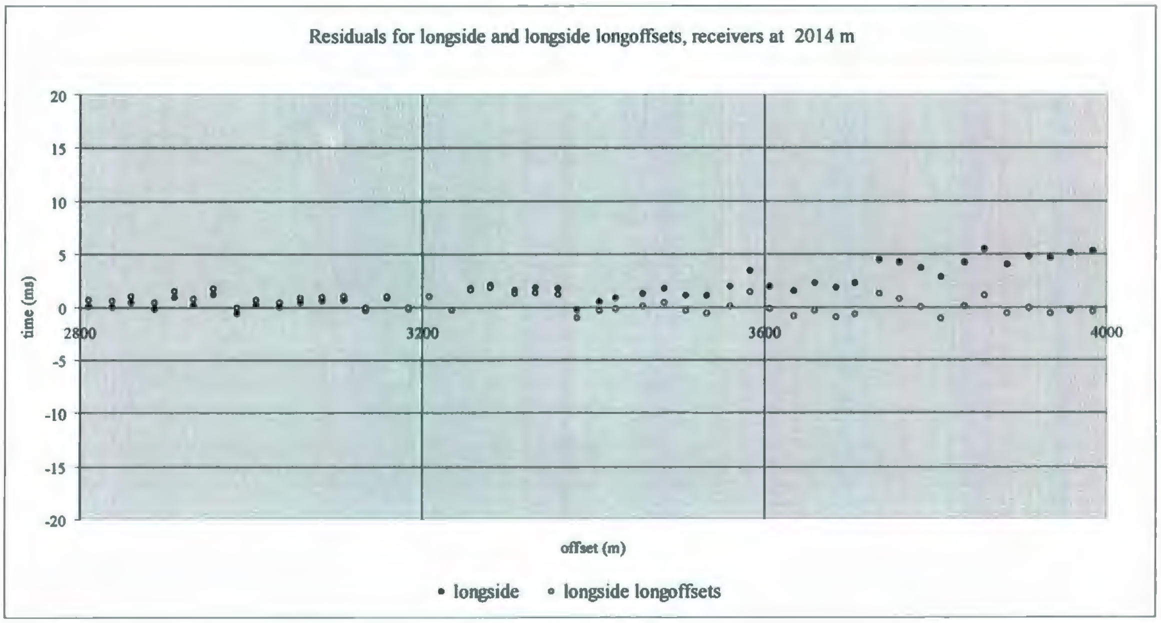
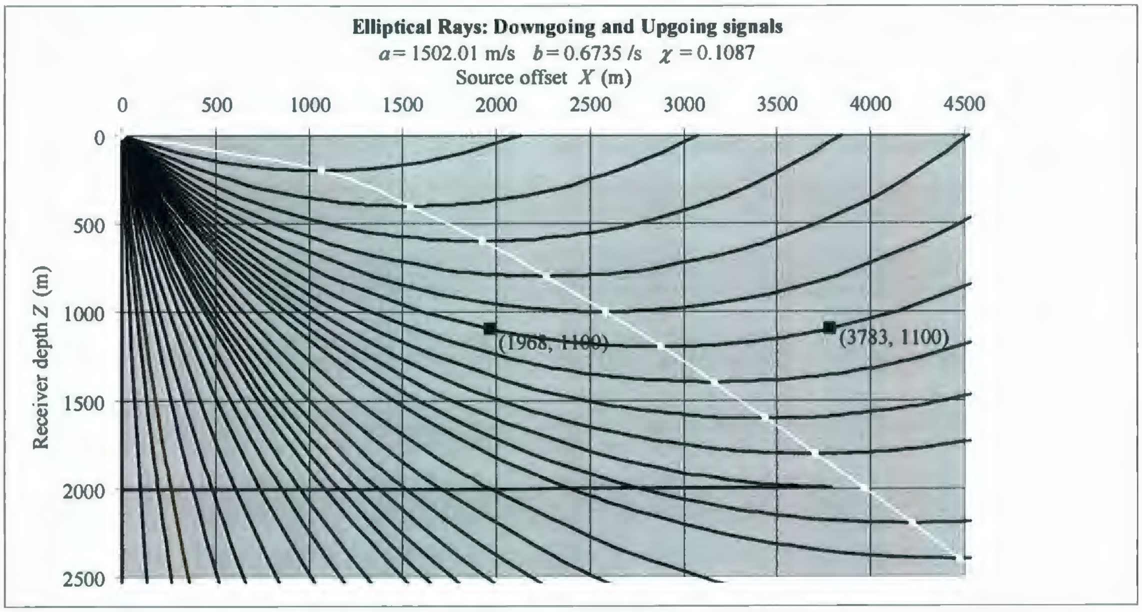


Figure 6.12: Comparison of residuals using all offsets vs. limiting the offsets to longoffsets only. For the shallow receiver, at 1974 m (above), the fit using values from the longoffsets only is better, white-dotted curve, than that obtained using all offsets, black-dotted curve; most of the points lie close to the axis. For the deeper receiver, at 2014 m (below) there is little difference, up to about 3200 m offset and then the white-dotted curve, the longoffsets only, is a better fit.

6.4 Forward-modelling Equations and Modification

6.4.1 Downgoing and Upgoing Signals (Turning Points)

Figures 6.13a and 6.13b show whether receivers in the borehole, for respective values of a, b, and χ, are reached by downgoing or upgoing signals. The signals travel along an elliptical arc and depending on the position of the receiver, the signal arriving is either upgoing or downgoing. The black curves are elliptical rays. The white curve in the xz-plane demarks the separation in locations, (x, z), reached by the downgoing signal from those reached by the upgoing signals, i.e., the turning point. The curve is a hyperbola. In Appendix G, we show an example computation. If the receiver position is such that it lies on the left of the white curve, it receives a downgoing signal. If the receiver position is to the right of the curve it receives an upgoing signal. For example, for a location with a source offset of 1968 m and receiver at depth 1100 m, the signal arriving would be downgoing. For a location with a source offset of 3783 m and receiver at depth 1100 m, the signal arriving would be upgoing for $a = 1502.014$ m/s, $b = 0.6735$ /s, $\chi = 0.1087$. This is useful information in the planning and designing of VSP surveys, since with a reasonable guess of a, b and χ one can determine the appropriate depths for receiver placements. Figure 6.13b shows the elliptical rays and turning points computed for a different set of values for a, b and χ ($a = 1358.17$ m/s, $b = 0.8726$ /s, $\chi = 0.0661$).



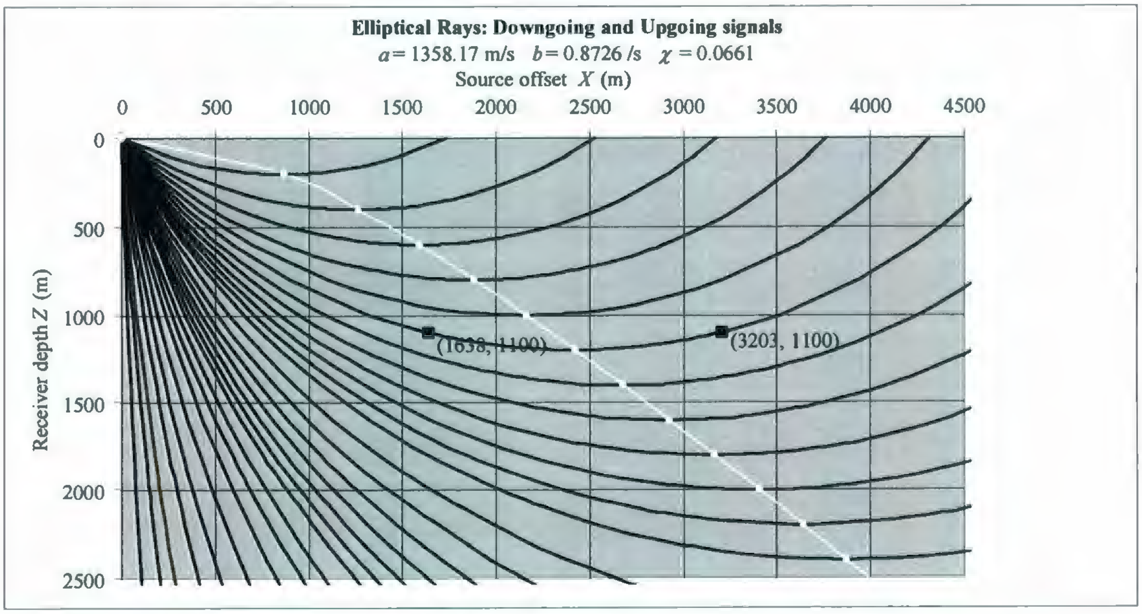


Figure 6.13a and 6.13b: Elliptical Rays (black curves) and turning points (white curve). Signals between sources and receivers travel along elliptical arcs. The white curve demarks the separation in locations, reached by the downgoing signal from those reached by the upgoing signals, (the turning point). If the receiver position is to the left of the white curve, it receives a downgoing signal. If the receiver position is to the right of the curve it receives an upgoing signal.

6.4.2 Original Equation and Reformulated Equation

Using expression (1.2) for forward modelling it was found that, depending on the values of a, b and χ, a cusp was observed at some offset after which the traveltimes decreased as shown in Figures 6.14a and 6.14b. It was realized that the cusp occurred at the 'turning point' of the ray and was as a result of the original traveltime equation being based on integration along the depth (z)-axis. Up to the turning point, the signal is downgoing and beyond the turning point, it is upgoing. The cusp arises because the traveltime for the upgoing ray is calculated with the opposite sign than that of the traveltime before the cusp, due to the change of the direction of integration that occurs by integrating along the z-axis. Physically, this is incorrect: this implies that traveltimes start decreasing from a certain point on. Thus, the original expression is valid only for downgoing rays. After reformulation of the traveltime equation to obtain expression (1.3), by integration performed along the offset (x)-axis, the cusp disappears, a single-valued function for the ray is obtained and the forward modelling can be extended to far offsets.

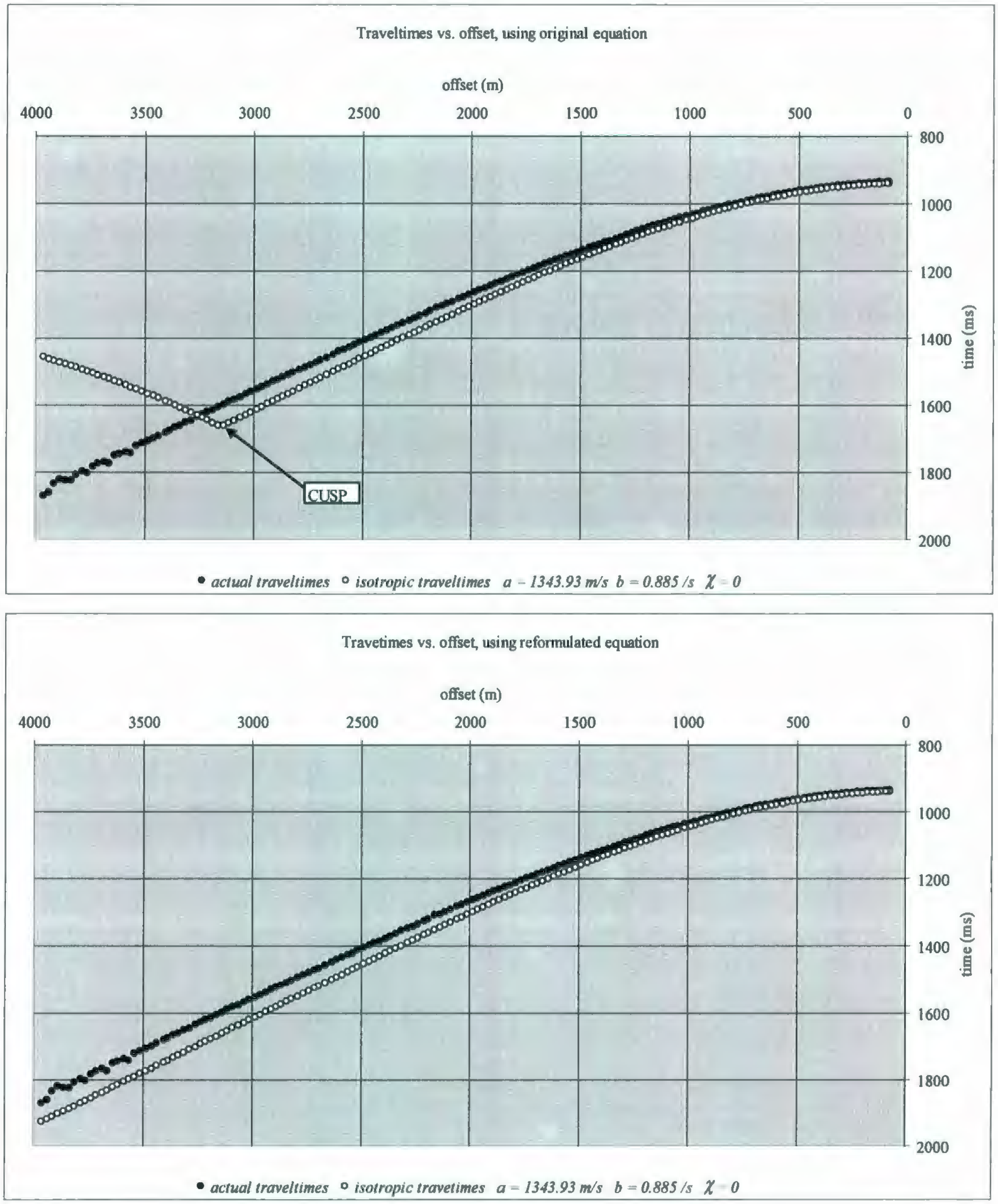


Figure 6.14a: Comparison of traveltimes from forward modelling using original and reformulated equations, for the isotropic case, illustrating cusp obtained with the original traveltime equation. The original equation was based on integration along the depth (z)-axis, whereas with the reformulated equation integration is performed along the offset (x)-axis and the cusp is corrected.

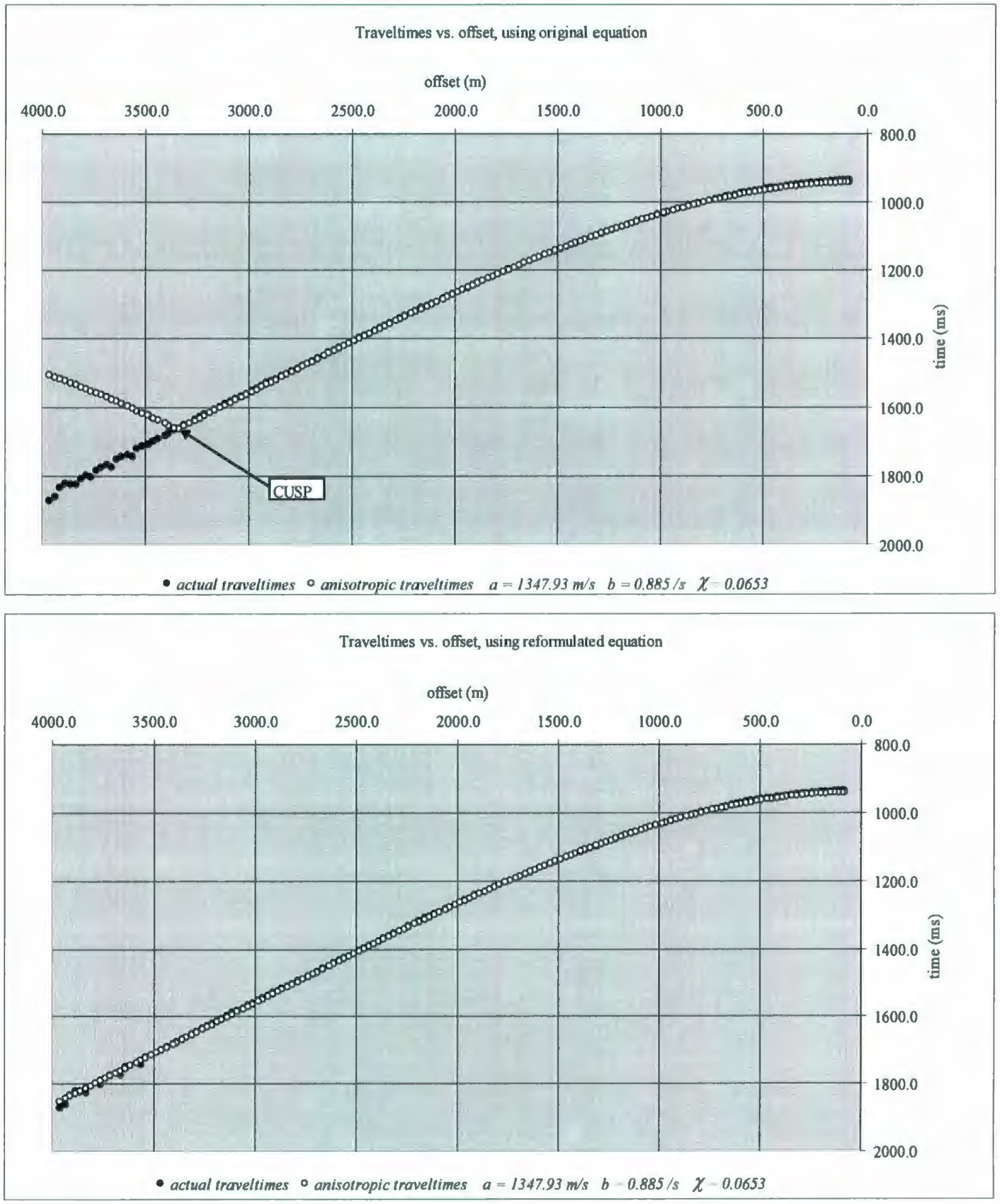


Figure 6.14b: Comparison of traveltimes from forward modelling using original and reformulated equations, for the anisotropic case, illustrating cusp obtained with the original traveltime equation. The original equation was based on integration along the depth (z)-axis, whereas with the reformulated equation integration is performed along the offset (x)-axis and the cusp is corrected.

CHAPTER 7: CONCLUSION AND RECOMMENDATIONS

Using the modified algorithm, Wheaton (2004), extensively on a large volume of real data to assess the algorithm was a test of the robustness of the methodology. It brought to light some shortcomings and enabled significant corrections that may otherwise have not been realized. The analytic equation for traveltime originally formulated was found to be applicable for short offsets, but had to be reformulated for long offsets so that only single-valued functions are obtained with offsets beyond the turning-ray offset. After reformulation, forward modelling was reliably attained for all offsets.

The algorithm appears to be fairly robust and is able to determine a and b in an isotropic medium and a, b, and χ in an anisotropic medium, provided initial guesses are reasonably realistic. Verifying parameters by forward modelling of the inverse results is an essential and necessary, but not sufficient, part of ensuring that reasonable values are obtained.

In our case, the effect of anisotropy is small. The best-fit value of the ellipticity parameter, χ, was found to be 0.0653. Although the anisotropy is small, it is sufficient to affect traveltimes, as has been demonstrated.

Because the anisotropy is small, to determine values correctly, the offset must be long, and traveltimes must be 'pickable' on the data. Discrepancies between models and reality can hinder any determination of χ.

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APPENDICES

APPENDIX A

Zero-offset (Vertical-incidence) VSP: Traveltimes

Table A.1: Observed traveltimes for zero-offset (vertical-incidence) VSP.

Measured receiver depth (KB) (m)	**Vertical receiver depth (MSL) (m)**	First-break traveltime (ms)	Source offset (m)	cos θ	**Observed (vertical) traveltime (msec)**	Measured receiver depth (KB) (m)	**Vertical receiver depth (MSL) (m)**	First-break traveltime (ms)	Source offset (m)	cos θ	**Observed (vertical) traveltime (msec)**
153.80	**130.80**	100.10	87.80	0.81776	**85.83**	2542.00	**1997.70**	941.90	19.85	0.99995	**945.79**
442.00	**418.60**	252.20	78.50	0.98236	**251.69**	2572.00	**2017.90**	949.20	0.26	1.00000	**953.14**
487.00	**463.10**	274.60	72.20	0.98774	**275.17**	2602.00	**2038.50**	957.60	20.61	0.99995	**961.49**
532.00	**507.40**	296.40	64.20	0.99190	**297.94**	2632.00	**2059.20**	965.70	8.39	0.99999	**969.63**
622.00	**595.10**	342.00	45.00	0.99709	**344.94**	2662.00	**2079.80**	972.90	8.97	0.99999	**976.83**
712.00	**681.50**	384.30	19.80	0.99957	**388.07**	2692.00	**2100.30**	980.20	19.47	0.99996	**984.09**
772.00	**738.10**	410.70	1.90	1.00000	**414.64**	2722.00	**2120.80**	987.70	0.90	1.00000	**991.64**
862.00	**820.90**	449.20	5.00	0.99998	**453.13**	2752.00	**2141.20**	995.50	21.56	0.99995	**999.39**
952.00	**901.30**	487.30	12.10	0.99991	**491.19**	2782.00	**2161.50**	1002.50	11.18	0.99999	**1006.42**
1012.00	**953.00**	510.40	7.00	0.99997	**514.32**	2812.00	**2181.80**	1009.70	10.57	0.99999	**1013.63**
1087.00	**1014.70**	540.50	8.00	0.99997	**544.42**	2842.00	**2202.00**	1016.80	23.21	0.99994	**1020.68**
1222.00	**1119.90**	585.10	0.30	1.00000	**589.04**	2872.00	**2222.00**	1023.00	1.71	1.00000	**1026.94**
1342.00	**1205.00**	621.40	21.20	0.99984	**625.24**	2902.00	**2241.80**	1030.50	20.68	0.99996	**1034.39**
1432.00	**1264.00**	647.90	10.00	0.99997	**651.82**	2932.00	**2261.60**	1036.90	10.50	0.99999	**1040.83**
1552.00	**1343.40**	681.40	22.20	0.99986	**685.24**	2962.00	**2281.40**	1041.30	8.91	0.99999	**1045.23**
1582.00	**1362.80**	690.50	11.90	0.99996	**694.41**	2992.00	**2301.10**	1046.30	21.84	0.99995	**1050.19**
1612.00	**1381.90**	698.30	9.50	0.99998	**702.22**	3022.00	**2320.90**	1050.90	1.34	1.00000	**1054.84**
1642.00	**1400.90**	705.90	21.10	0.99989	**709.76**	3052.00	**2340.60**	1055.70	21.13	0.99996	**1059.59**
1672.00	**1419.60**	713.70	1.00	1.00000	**717.64**	3082.00	**2360.50**	1061.40	11.28	0.99999	**1065.32**
1702.00	**1438.10**	721.10	23.50	0.99987	**724.94**	3112.00	**2380.40**	1066.40	8.85	0.99999	**1070.33**
1732.00	**1456.60**	729.50	12.20	0.99996	**733.41**	3142.00	**2400.50**	1071.70	20.43	0.99996	**1075.60**
1762.00	**1475.20**	736.50	10.60	0.99997	**740.42**	3172.00	**2420.70**	1076.30	0.09	1.00000	**1080.24**
1792.00	**1494.20**	744.20	21.30	0.99990	**748.06**	3202.00	**2440.70**	1082.00	23.22	0.99995	**1085.89**
1822.00	**1513.90**	751.90	0.70	1.00000	**755.84**	3232.00	**2460.70**	1086.70		1.00000	**1090.64**
1852.00	**1534.10**	761.00	22.30	0.99989	**764.86**	3262.00	**2480.60**	1091.80	9.75	0.99999	**1095.73**
1882.00	**1554.60**	769.80	9.60	0.99998	**773.72**	3292.00	**2500.40**	1096.80	19.03	0.99997	**1100.71**
1912.00	**1574.90**	777.40	9.50	0.99998	**781.32**	3322.00	**2520.30**	1101.80	0.56	1.00000	**1105.74**
1942.00	**1595.10**	785.70	21.10	0.99991	**789.57**	3352.00	**2540.30**	1107.40	18.99	0.99997	**1111.31**
1972.00	**1615.20**	793.10	0.40	1.00000	**797.04**	3382.00	**2560.20**	1113.50	10.12	0.99999	**1117.43**
2002.00	**1635.40**	801.20	21.10	0.99992	**805.07**	3412.00	**2580.20**	1117.80	5.51	1.00000	**1121.73**
2032.00	**1655.50**	809.20	8.90	0.99999	**813.13**	3472.00	**2620.50**	1127.60	0.73	1.00000	**1131.54**
2062.00	**1675.60**	816.60	10.20	0.99998	**820.52**	3502.00	**2640.60**	1133.00	21.28	0.99997	**1136.90**
2092.00	**1695.90**	823.80	22.00	0.99991	**827.67**	3532.00	**2660.90**	1137.80	11.78	0.99999	**1141.73**
2122.00	**1716.10**	831.70	1.00	1.00000	**835.64**	3562.00	**2681.10**	1142.50	9.90	0.99999	**1146.43**
2152.00	**1736.20**	839.50	20.69	0.99993	**843.38**	3592.00	**2701.30**	1146.60	21.52	0.99997	**1150.50**
2182.00	**1756.40**	848.10	8.08	0.99999	**852.03**	3622.00	**2721.70**	1151.20	1.52	1.00000	**1155.14**
2212.00	**1776.40**	855.90	10.19	0.99998	**859.82**	3652.00	**2742.00**	1156.80	18.39	0.99998	**1160.71**
2242.00	**1796.60**	863.70	21.81	0.99993	**867.57**	3682.00	**2762.20**	1161.50	11.41	0.99999	**1165.43**
2272.00	**1816.90**	872.00	1.06	1.00000	**875.94**	3712.00	**2782.10**	1165.80	9.39	0.99999	**1169.73**
2302.00	**1837.10**	880.60	21.26	0.99993	**884.48**	3742.00	**2802.00**	1171.50	22.07	0.99997	**1175.40**
2332.00	**1857.30**	888.20	9.95	0.99999	**892.12**	3772.00	**2822.20**	1175.40	1.51	1.00000	**1179.34**
2362.00	**1877.60**	895.80	9.57	0.99999	**899.73**	3802.00	**2842.70**	1181.20	21.27	0.99997	**1185.10**
2392.00	**1897.80**	904.00	20.23	0.99994	**907.89**	3832.00	**2863.50**	1185.90	8.76	1.00000	**1189.83**
2422.00	**1917.80**	911.10	0.62	1.00000	**915.04**	3862.00	**2884.40**	1191.50	9.23	0.99999	**1195.43**
2452.00	**1938.00**	918.70	20.77	0.99994	**922.58**	3892.00	**2905.40**	1196.30	22.88	0.99997	**1200.20**
2482.00	**1958.10**	926.80	12.94	0.99998	**930.72**	3922.00	**2926.30**	1201.20	1.33	1.00000	**1205.14**
2512.00	**1977.90**	934.10	6.21	1.00000	**938.03**	3952.00	**2947.30**	1206.00	19.83	0.99998	**1209.91**

$$\text{Observed (vertical) traveltime} = (\text{First-break traveltime} \; * \cos\theta) + \left[\frac{\text{Source depth}}{\text{Water velocity}}\right]$$

$$\theta = \tan^{-1}\left[\frac{\text{Source offset}}{\text{Vertical receiver depth - Source depth}}\right]$$

Example:

First-break traveltime: 252.2 ms = 0.2522 s

cosθ: 0.98236

Source depth: 6.0 m

Water velocity: 1524.0 m/s

$$\text{Observed (vertical) traveltime} = (0.2522 * 0.98236) + \left[\frac{6.0}{1524.0}\right] = 0.2517\text{s} = 251.7\text{ ms}$$

APPENDIX B

Walkaround VSP: Traveltimes

Two adjustments were applied to the traveltimes to remove the effects of variations in source and receiver positions, effectively normalizing the data to a single receiver and single source. The corrections applied are described below and example calculations are shown. Figure B.1 illustrates the layout for a source at surface and the eight-level receiver array in the well. Table B.1 lists corrected traveltimes.

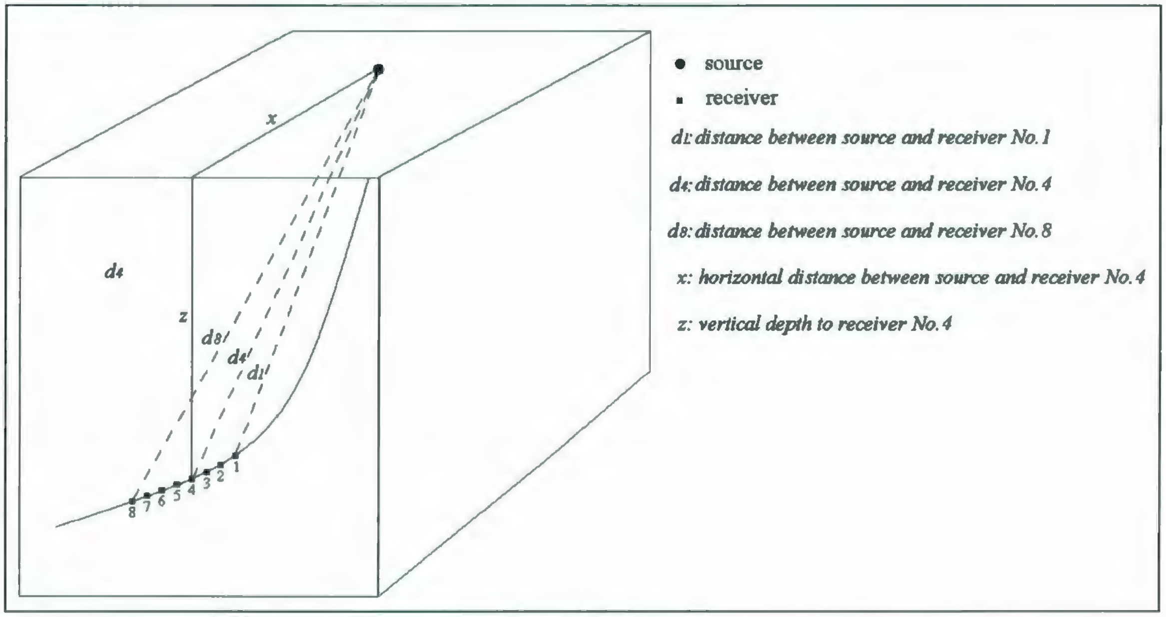

Figure B.1: Layout for a source at surface with the eight-level receiver array in the well. The distance from a source position to each receiver varies. Traveltimes were adjusted to account for this variation.

1. Traveltimes recorded were adjusted with respect to a reference receiver (No.4), to account for the difference in source-to-receiver distances due to variations in receiver positioning. The ratio of the distances from a given source position to the reference receiver and to a receiver for which the traveltime is to be adjusted was applied as shown in expression B.1.

$$t_{an} = \frac{d_4}{d_n} \times t_{rn}, \tag{B.1}$$

where t_{an} is the adjusted traveltime and t_{rn} is the recorded traveltime for receiver *n*, $n = 1 \ldots 8$.

Example:

Distance between source No.1 and receiver No.1 (d_1): 2606.37 m.

Distance between source No.1 and receiver No.4 (d_4): 2648.90 m.

Distance between source No.1 and receiver No.8 (d_8): 2705.89 m.

$$d_1 - d_4 = 2606.37\ m - 2648.90\ m = -42.53\ m$$

$$d_8 - d_4 = 2705.90\ m - 2648.90\ m = 57.00\ m$$

$$t_{a1} = \frac{d_4}{d_1} \times t_{r1}$$

$$t_{a1} = \frac{2648.90m}{2606.37m} \times 1.180576s = 1.199841s = 1.19984s$$

$$t_{a8} = \frac{2648.90m}{2705.89m} \times 1.214355s = 1.188777s = 1.18878s$$

2. Adjusted traveltimes obtained, as described above, were further corrected for the variation in source to receiver distances due to source positioning. Sources were placed radially around the receiver array as shown in Figure 2.5. Source No.14 was used as the reference source for this correction. The ratio of the distances between the reference source and source for which the traveltime is to be corrected was applied as shown in expression B.2.

$$t_{cm} = \frac{s_{14}}{s_m} \times t_{sm}, \tag{B.2}$$

where t_{cm} is the corrected traveltime and t_{sm} is the adjusted traveltime, referenced to receiver No.4, for source m, $m = 1 \ldots 14$.

Example:

Distance between source No.1 and receiver No.4: 2648.90 m.

Distance between source No.14 and receiver No.4: 2645.19 m.

Distance between source No.7 and receiver No.4: 2636.58 m.

$$t_{c1} = \frac{s_{14}}{s_1} \times t_{s1}$$

$$t_{c1} = \frac{2645.19m}{2648.90m} \times 1.199841s = 1.198160s = 1.19816s$$

$$t_{c7} = \frac{2645.19m}{2636.58m} \times 1.198389s = 1.202302s = 1.20230s$$

Corrections can applied with respect to a reference receiver and then with respect to a reference source or *vice versa*. Table B.1 provides traveltimes adjusted to a reference receiver (No.4), adjusted to a reference source (No.14), and corrected to both the reference receiver and the reference source.

Table B.1: Traveltimes corrected for variations arising due to source and receiver positioning. Traveltimes adjusted to a reference receiver (No.4), adjusted to a reference source (No.14), and corrected to both the reference receiver and the reference source are shown.

Source Point No.	Source to receiver azimuth (°)	Source to receiver horizontal distance (m)	Receiver vertical depth from msl (m)	Source to receiver distance (m)	Measured traveltime (s)	Adjusted traveltime referenced to receiver No.4 (s)	Adjusted traveltime referenced to SP 14	Corrected traveltime referenced to receiver No.4 and SP 14 (s)
1	359.81	1487.51	2146.20	2606.37	1.180576	1.199841	1.180817	1.198160
	-0.02	1497.50	2156.41	2620.45	1.185670	1.198541	1.185268	1.196861
	0.15	1507.51	2166.60	2634.53	1.190809	1.197301	1.189771	1.195623
	0.32	1518.02	2176.78	2648.90	1.195791	1.195791	1.194115	1.194115
	0.49	1528.56	2186.93	2663.25	1.200804	1.194331	1.198499	1.192658
	0.65	1539.10	2197.05	2677.60	1.204522	1.191611	1.201599	1.189941
	0.81	1549.16	2207.12	2691.62	1.209796	1.190593	1.206268	1.188925
	0.98	1559.73	2217.13	2705.89	1.214355	1.188777	1.210216	1.187112
2	27.16	1483.07	2146.20	2603.83	1.177265	1.197211	1.178650	1.195961
	27.14	1494.02	2156.41	2618.47	1.182531	1.195847	1.183027	1.194598
	27.12	1504.97	2166.60	2633.09	1.187778	1.194483	1.187395	1.193236
	27.09	1516.37	2176.78	2647.95	1.193021	1.193021	1.191776	1.191776
	27.06	1527.77	2186.93	2662.80	1.198222	1.191539	1.196125	1.190295
	27.03	1539.16	2197.05	2677.64	1.202021	1.188695	1.199087	1.187454
	27.01	1550.12	2207.12	2692.18	1.207618	1.187780	1.203848	1.186540
	26.99	1561.54	2217.13	2706.94	1.212334	1.185915	1.207734	1.184677
3	45.34	1493.13	2146.20	2609.58	1.183625	1.203072	1.182411	1.199777
	45.19	1503.36	2156.41	2623.81	1.188667	1.201644	1.186745	1.198353
	45.04	1513.61	2166.60	2638.03	1.193723	1.200248	1.191102	1.196961
	44.88	1524.22	2176.78	2652.45	1.198775	1.198775	1.195491	1.195491
	44.72	1534.84	2186.93	2666.86	1.203769	1.197263	1.199832	1.193984
	44.57	1545.47	2197.05	2681.27	1.207414	1.194439	1.202836	1.191167
	44.43	1555.76	2207.12	2695.43	1.212903	1.193565	1.207659	1.190296
	44.28	1566.45	2217.13	2709.78	1.217497	1.191742	1.211609	1.188477
4	67.86	1489.92	2146.20	2607.74	1.181961	1.199595	1.181579	1.198933
	67.57	1497.87	2156.41	2620.67	1.186488	1.198251	1.185989	1.197589
	67.28	1505.87	2166.60	2633.60	1.190787	1.196688	1.190172	1.196027
	66.98	1514.09	2176.78	2646.65	1.195362	1.195362	1.194702	1.194702
	66.69	1522.36	2186.93	2659.70	1.199723	1.193834	1.199018	1.193174
	66.39	1530.67	2197.05	2672.76	1.202706	1.190955	1.201958	1.190297
	66.12	1538.82	2207.12	2685.68	1.207619	1.190067	1.206759	1.189409
	65.83	1547.26	2217.13	2698.72	1.211687	1.188306	1.210765	1.187649
5	90.59	1496.14	2146.20	2611.30	1.181047	1.195881	1.179055	1.196372
	90.21	1500.57	2156.41	2622.21	1.184600	1.194489	1.183405	1.194980
	89.83	1505.07	2166.60	2633.14	1.188293	1.193239	1.187885	1.193729
	89.43	1509.64	2176.78	2644.10	1.192145	1.192145	1.192634	1.192634
	89.04	1514.28	2186.93	2655.08	1.195878	1.190931	1.197255	1.191420
	88.64	1518.99	2197.05	2666.09	1.198432	1.188548	1.200684	1.189036
	88.27	1523.76	2207.12	2677.08	1.202638	1.187821	1.205642	1.188309
	87.88	1528.67	2217.13	2688.11	1.205965	1.186221	1.209805	1.186708
6	112.89	1502.42	2146.20	2614.91	1.186092	1.197712	1.182460	1.199827
	112.48	1502.72	2156.41	2623.44	1.188914	1.196657	1.187159	1.198770
	112.06	1503.09	2166.60	2632.01	1.191880	1.195734	1.191982	1.197846
	111.62	1503.36	2176.78	2640.52	1.195018	1.195018	1.197128	1.197128
	111.19	1503.72	2186.93	2649.08	1.198035	1.194166	1.202134	1.196275
	110.75	1504.16	2197.05	2657.67	1.199630	1.191890	1.205692	1.193995
	110.34	1504.87	2207.12	2666.38	1.202864	1.191201	1.210711	1.193304
	109.90	1505.54	2217.13	2675.02	1.205548	1.190000	1.215303	1.192101
7	135.40	1508.34	2146.20	2618.31	1.190086	1.198389	1.184899	1.202302
	135.01	1504.41	2156.41	2624.41	1.192038	1.197565	1.189837	1.201475
	134.62	1500.56	2166.60	2630.57	1.194196	1.196926	1.194955	1.200833
	134.21	1496.42	2176.78	2636.58	1.196383	1.196383	1.200289	1.200289
	133.80	1492.36	2186.93	2642.65	1.198493	1.195740	1.205519	1.199644
	133.39	1488.38	2197.05	2648.77	1.199071	1.193551	1.209179	1.197448
	132.99	1484.82	2207.12	2655.11	1.201366	1.192979	1.214333	1.196874
	132.57	1481.04	2217.13	2661.31	1.203122	1.191942	1.219107	1.195833

Source Point No.	Source to receiver azimuth (°)	Source to receiver horizontal distance (m)	Receiver vertical depth from msl (m)	Source to receiver distance (m)	Measured traveltime (s)	Adjusted traveltime referenced to receiver No.4 (s)	Adjusted traveltime referenced to SP 14	Corrected traveltime referenced to receiver No.4 and SP 14 (s)
8	202.67	1512.36	2146.20	2620.63	1.194752	1.197537	1.188492	1.205948
	202.66	1501.40	2156.41	2622.68	1.195008	1.196855	1.193587	1.205261
	202.65	1490.44	2166.60	2624.81	1.195382	1.196262	1.198767	1.204664
	202.64	1479.01	2176.78	2626.74	1.195692	1.195692	1.204090	1.204090
	202.64	1467.59	2186.93	2628.74	1.196259	1.195348	1.209640	1.203744
	202.64	1456.17	2197.05	2630.80	1.196324	1.194474	1.214648	1.202864
	202.62	1445.21	2207.12	2633.17	1.194693	1.191776	1.217653	1.200147
	202.62	1433.76	2217.13	2635.29	1.197501	1.193613	1.225391	1.201996
9	225.20	1514.99	2146.20	2622.14	1.192519	1.195877	1.185585	1.202998
	225.35	1504.75	2156.41	2624.60	1.192817	1.195055	1.190527	1.202171
	225.50	1494.53	2166.60	2627.13	1.193313	1.194402	1.195633	1.201514
	225.67	1483.96	2176.78	2629.53	1.193739	1.193739	1.200848	1.200848
	225.84	1473.41	2186.93	2631.99	1.194408	1.193289	1.206274	1.200395
	226.01	1462.88	2197.05	2634.52	1.194525	1.192259	1.211109	1.199359
	226.17	1452.70	2207.12	2637.29	1.193010	1.189500	1.214038	1.196583
	226.35	1442.14	2217.13	2639.86	1.194914	1.190235	1.220626	1.197323
10	247.20	1510.99	2146.20	2619.84	1.192137	1.197301	1.186250	1.203672
	247.49	1502.98	2156.41	2623.59	1.193144	1.196598	1.191313	1.202965
	247.77	1495.02	2166.60	2627.41	1.194933	1.196651	1.197129	1.203018
	248.08	1486.90	2176.78	2631.19	1.195333	1.195333	1.201693	1.201693
	248.40	1478.83	2186.93	2635.03	1.196964	1.195219	1.207463	1.201578
	248.71	1470.80	2197.05	2638.93	1.196909	1.193396	1.211499	1.199746
	249.01	1463.00	2207.12	2642.97	1.197380	1.192040	1.215864	1.198383
	249.33	1455.00	2217.13	2646.91	1.198415	1.191296	1.220945	1.197635
11	269.66	1507.96	2146.20	2618.09	1.189698	1.197626	1.184611	1.202009
	270.04	1503.44	2156.41	2623.85	1.191255	1.196562	1.189309	1.200942
	270.42	1498.98	2166.60	2629.66	1.193167	1.195833	1.194335	1.200210
	270.82	1494.59	2176.78	2635.54	1.194854	1.194854	1.199227	1.199227
	271.23	1490.28	2186.93	2641.47	1.196741	1.194053	1.204293	1.198423
	271.64	1486.05	2197.05	2647.46	1.197197	1.191807	1.207888	1.196169
	272.03	1481.87	2207.12	2653.46	1.199276	1.191175	1.212974	1.195534
	272.44	1477.72	2217.13	2659.47	1.200869	1.190066	1.217669	1.194421
12	291.95	1499.68	2146.20	2613.33	1.186885	1.198089	1.183963	1.201352
	292.37	1499.28	2156.41	2621.47	1.189364	1.196863	1.188498	1.200123
	292.78	1498.97	2166.60	2629.66	1.191873	1.195654	1.193042	1.198911
	293.22	1498.93	2176.78	2638.00	1.194174	1.194174	1.197426	1.197426
	293.66	1498.98	2186.93	2646.39	1.196862	1.193069	1.202178	1.196318
	294.09	1499.11	2197.05	2654.82	1.198182	1.190594	1.205532	1.193836
	294.51	1499.13	2207.12	2663.14	1.201070	1.189732	1.210374	1.192972
	294.95	1499.38	2217.13	2671.56	1.203406	1.188290	1.214717	1.191526
13	314.46	1496.26	2146.20	2611.37	1.186359	1.200885	1.184328	1.201722
	314.85	1500.09	2156.41	2621.93	1.190034	1.199752	1.188959	1.200588
	315.24	1503.99	2166.60	2632.52	1.193866	1.198774	1.193737	1.199609
	315.65	1508.31	2176.78	2643.34	1.197490	1.197490	1.198325	1.198325
	316.05	1512.71	2186.93	2654.19	1.201128	1.196219	1.202916	1.197053
	316.44	1517.18	2197.05	2665.06	1.203274	1.193469	1.206001	1.194301
	316.83	1521.36	2207.12	2675.72	1.207288	1.192679	1.210920	1.193511
	317.22	1525.93	2217.13	2686.55	1.210394	1.190926	1.214951	1.191756
14	337.24	1488.44	2146.20	2606.90	1.181058	1.198404	1.181058	1.198404
	337.54	1495.94	2156.41	2619.56	1.185591	1.197188	1.185591	1.197188
	337.85	1503.49	2166.60	2632.24	1.190270	1.196125	1.190270	1.196125
	338.16	1511.54	2176.78	2645.19	1.194668	1.194668	1.194668	1.194668
	338.46	1519.63	2186.93	2658.14	1.199249	1.193404	1.199249	1.193404
	338.76	1527.77	2197.05	2671.10	1.202408	1.190743	1.202408	1.190743
	339.05	1535.48	2207.12	2683.77	1.207210	1.189854	1.207210	1.189854
	339.35	1543.67	2217.13	2696.67	1.211217	1.188093	1.211217	1.188093

APPENDIX C

Walkaway VSP: Traveltimes

Table C.1: Traveltimes for Receiver 1.

Receiver Depth = 1973.923 m											
Source N.o.	Source Offset (m)	Traveltime (ms)	Source N.o.	Source Offset (m)	Traveltime (ms)	Source N.o.	Source Offset (m)	Traveltime (ms)	Source N.o.	Source Offset (m)	Traveltime (ms)
1	1014.078	1036.432	51	244.406	941.458	101	1485.368	1136.798	151	2737.504	1478.316
2	989.797	1031.409	52	270.447	942.481	102	1513.211	1143.508	152	2763.498	1486.156
3	966.288	1027.439	53	293.032	944.033	103	1539.303	1149.417	153	2790.900	1492.776
4	941.466	1023.055	54	317.805	945.562	104	1565.130	1154.933	154	2818.515	1501.544
5	915.969	1018.204	55	343.415	947.720	105	1588.644	1160.874	155	2840.130	1509.010
6	889.718	1014.435	56	369.719	949.464	106	1612.475	1167.062	156	2867.558	1516.612
7	864.303	1010.473	57	393.092	952.038	107	1638.883	1173.549	157	2891.097	1522.475
8	841.107	1005.947	58	417.457	953.379	108	1663.079	1178.955	158	2913.083	1527.969
9	816.118	1002.145	59	443.392	956.346	109	1689.771	1185.425	159	2936.480	1537.739
10	788.795	998.318	60	465.151	958.015	110	1711.871	1191.324	160	2963.685	1544.497
11	765.793	994.844	61	493.184	960.078	111	1739.048	1197.521	161	2985.984	1551.710
12	740.308	991.292	62	515.711	963.346	112	1763.081	1203.817	162	3013.154	1560.112
13	716.162	987.772	63	541.511	965.572	113	1789.370	1210.837	163	3037.280	1566.471
14	694.514	985.218	64	566.218	968.150	114	1814.387	1217.784	164	3062.143	1575.806
15	663.944	980.535	65	594.084	971.846	115	1836.461	1223.474	165	3087.867	1582.710
16	642.565	977.875	66	616.525	974.437	116	1863.985	1231.080	166	3113.355	1587.800
17	617.231	975.246	67	640.390	977.709	117	1888.688	1235.614	167	3137.870	1597.852
18	591.674	971.165	68	666.096	980.848	118	1912.386	1242.405	168	3163.910	1605.218
19	568.580	968.847	69	686.674	983.892	119	1936.696	1250.340	169	3187.722	1614.170
20	538.050	966.045	70	714.131	987.625	120	1962.993	1255.989	170	3214.578	1620.041
21	515.799	963.125	71	734.065	990.735	121	1986.236	1262.363	171	3236.351	1627.195
22	489.340	960.062	72	763.765	994.462	122	2011.513	1269.025	172	3259.675	1634.435
23	469.040	958.225	73	790.341	998.943	123	2038.012	1276.389	173	3288.287	1645.422
24	444.262	955.686	74	818.537	1002.359	124	2058.654	1281.452	174	3312.831	1651.273
25	418.215	953.700	75	838.613	1006.107	125	2089.406	1291.095	175	3338.804	1660.710
26	394.946	951.439	76	864.183	1009.904	126	2113.127	1297.340	176	3361.215	1665.429
27	373.059	949.506	77	889.644	1015.459	127	2137.010	1304.095	177	3387.640	1674.863
28	344.072	948.215	78	916.870	1018.333	128	2162.001	1308.005	178	3405.836	1681.033
29	324.116	946.461	79	938.114	1022.636	129	2190.353	1318.307	179	3438.279	1690.683
30	297.101	944.746	80	967.871	1028.093	130	2208.538	1324.103	180	3462.882	1698.660
31	275.418	943.693	81	984.094	1032.088	131	2240.131	1332.692	181	3488.647	1706.745
32	246.708	941.976	82	1014.404	1035.925	132	2262.848	1340.505	182	3512.857	1712.753
33	225.285	940.090	83	1043.220	1041.995	133	2285.069	1346.629	183	3539.715	1720.417
34	201.211	938.334	84	1065.184	1046.384	134	2313.522	1354.231	184	3562.825	1742.573
35	182.634	937.775	85	1088.895	1050.471	135	2338.818	1361.689	185	3586.331	1738.627
36	151.037	937.281	86	1115.015	1055.210	136	2364.031	1368.898	186	3614.704	1743.987
37	136.395	936.890	87	1140.098	1060.235	137	2387.757	1376.166	187	3639.544	1750.378
38	119.615	936.139	88	1165.295	1065.256	138	2414.140	1384.134	188	3664.411	1773.884
39	94.406	935.931	89	1187.085	1070.389	139	2438.493	1389.482	189	3686.858	1767.780
40	82.931	935.126	90	1214.352	1075.694	140	2462.794	1396.500	190	3715.162	1773.923
41	76.916	935.534	91	1238.248	1080.502	141	2487.398	1404.673	191	3738.511	1782.683
42	74.741	935.336	92	1262.578	1085.769	142	2515.010	1412.021	192	3763.146	1802.645
43	84.530	935.707	93	1288.093	1092.119	143	2538.668	1420.411	193	3787.190	1796.954
44	93.234	935.612	94	1312.260	1097.591	144	2561.908	1425.506	194	3813.895	1807.817
45	112.705	936.244	95	1337.566	1102.887	145	2586.946	1432.678	195	3837.164	1825.078
46	130.648	936.110	96	1366.579	1110.075	146	2611.466	1439.409	196	3863.906	1823.494
47	152.613	937.377	97	1386.806	1113.877	147	2634.472	1447.930	197	3889.009	1820.780
48	176.332	938.209	98	1413.235	1120.171	148	2664.740	1457.009	198	3914.736	1833.245
49	200.664	939.183	99	1434.249	1125.078	149	2693.145	1465.913	199	3937.224	1860.562
50	222.033	940.566	100	1457.820	1129.865	150	2713.475	1471.688	200	3964.125	1870.558

Table C.2: Traveltimes for Receiver 2.

Receiver Depth = 1983.809 m											
Source N.o.	Source Offset (m)	Traveltime (ms)	Source N.o.	Source Offset (m)	Traveltime (ms)	Source N.o.	Source Offset (m)	Traveltime (ms)	Source N.o.	Source Offset (m)	Traveltime (ms)
201	1008.351	1038.840	251	247.111	945.205	301	1490.113	1140.644	351	2742.351	1481.698
202	984.043	1033.122	252	273.339	946.367	302	1517.949	1147.233	352	2768.347	1489.435
203	960.508	1029.148	253	296.045	947.988	303	1544.086	1153.155	353	2795.751	1496.836
204	935.676	1025.027	254	321.033	949.649	304	1569.900	1158.895	354	2823.373	1504.003
205	910.130	1021.168	255	346.827	952.137	305	1593.404	1164.270	355	2845.001	1510.775
206	883.891	1017.319	256	373.160	953.549	306	1617.242	1170.602	356	2872.444	1517.430
207	858.483	1013.209	257	396.718	955.886	307	1643.658	1177.444	357	2895.995	1527.097
208	835.240	1008.312	258	421.107	957.665	308	1667.848	1182.653	358	2917.992	1531.993
209	810.244	1004.878	259	447.157	960.745	309	1694.537	1189.136	359	2941.398	1540.569
210	782.892	1001.203	260	469.001	962.260	310	1716.647	1194.793	360	2968.622	1546.735
211	759.852	997.567	261	497.013	964.153	311	1743.842	1201.199	361	2990.918	1553.385
212	734.346	994.381	262	519.641	967.471	312	1767.872	1207.696	362	3018.090	1561.528
213	710.170	990.638	263	545.499	969.745	313	1794.159	1214.073	363	3042.218	1568.398
214	688.527	988.177	264	570.228	972.201	314	1819.208	1220.868	364	3067.084	1576.207
215	657.899	983.886	265	598.156	975.986	315	1841.269	1226.550	365	3092.811	1585.550
216	636.545	981.287	266	620.641	978.617	316	1868.805	1233.862	366	3118.302	1590.731
217	611.188	977.982	267	644.580	981.874	317	1893.512	1240.130	367	3142.820	1600.101
218	585.598	974.139	268	670.325	985.060	318	1917.232	1246.604	368	3168.861	1608.303
219	562.487	971.586	269	691.031	988.157	319	1941.535	1253.548	369	3192.675	1615.857
220	531.796	968.724	270	718.482	991.753	320	1967.839	1259.847	370	3219.534	1622.663
221	509.525	966.093	271	738.482	994.879	321	1991.090	1265.565	371	3241.315	1631.572
222	483.059	963.084	272	768.171	998.693	322	2016.374	1273.312	372	3264.630	1638.071
223	462.703	961.095	273	794.790	1002.989	323	2042.866	1280.025	373	3293.246	1647.669
224	437.891	958.631	274	822.941	1006.748	324	2063.524	1285.407	374	3317.799	1653.441
225	411.844	956.849	275	843.036	1010.184	325	2094.281	1294.071	375	3343.766	1662.421
226	388.454	954.877	276	868.614	1013.894	326	2117.996	1299.952	376	3366.177	1667.257
227	366.440	953.134	277	894.119	1019.595	327	2141.883	1307.700	377	3392.607	1675.520
228	337.400	951.426	278	921.307	1022.321	328	2166.886	1310.301	378	3410.802	1681.964
229	317.048	949.415	279	942.569	1027.050	329	2195.224	1323.274	379	3443.246	1691.929
230	289.835	947.845	280	972.347	1032.722	330	2213.413	1327.841	380	3467.846	1710.587
231	267.858	946.987	281	988.598	1036.735	331	2245.016	1336.037	381	3493.613	1709.635
232	239.050	945.197	282	1018.913	1040.235	332	2267.713	1343.859	382	3517.821	1713.031
233	217.478	943.625	283	1047.728	1045.885	333	2289.923	1348.996	383	3544.681	1722.879
234	193.088	942.345	284	1069.727	1050.348	334	2318.389	1357.301	384	3567.794	1741.318
235	174.105	941.309	285	1093.448	1054.671	335	2343.698	1365.345	385	3591.299	1736.081
236	142.494	940.727	286	1119.573	1059.151	336	2368.914	1372.069	386	3619.680	1747.966
237	126.875	940.937	287	1144.664	1064.439	337	2392.644	1379.635	387	3644.514	1752.301
238	109.503	939.762	288	1169.907	1069.724	338	2419.031	1386.817	388	3669.383	1778.166
239	83.743	939.623	289	1191.722	1074.964	339	2443.401	1392.626	389	3691.832	1770.612
240	71.966	938.903	290	1219.006	1080.203	340	2467.697	1400.358	390	3720.138	1775.954
241	66.459	939.149	291	1242.914	1084.769	341	2492.313	1408.040	391	3743.487	1783.222
242	66.310	939.227	292	1267.262	1090.486	342	2519.922	1415.364	392	3768.123	1791.143
243	78.328	939.528	293	1292.784	1096.443	343	2543.581	1422.726	393	3792.172	1802.154
244	89.803	939.563	294	1316.929	1101.800	344	2566.833	1429.279	394	3818.878	1808.063
245	111.608	940.394	295	1342.261	1107.092	345	2591.883	1436.051	395	3842.148	1812.050
246	130.642	940.091	296	1371.339	1113.786	346	2616.403	1443.447	396	3868.893	1834.522
247	153.154	941.688	297	1391.577	1118.027	347	2639.425	1451.370	397	3893.998	1832.293
248	177.687	942.350	298	1418.030	1124.079	348	2669.654	1459.092	398	3919.728	1841.510
249	202.354	943.109	299	1439.032	1129.362	349	2698.020	1468.384	399	3942.218	1849.791
250	224.320	944.924	300	1462.608	1134.666	350	2718.334	1472.716	400	3969.119	1856.989

Table C.3: Traveltimes for Receiver 3.

Receiver Depth = 1993.699 m											
Source N.o.	Source Offset (m)	Traveltime (ms)	Source N.o.	Source Offset (m)	Traveltime (ms)	Source N.o.	Source Offset (m)	Traveltime (ms)	Source N.o.	Source Offset (m)	Traveltime (ms)
401	1002.711	1040.296	451	250.268	949.125	501	1494.924	1144.481	551	2747.233	1483.652
402	978.378	1034.723	452	276.636	950.369	502	1522.751	1151.295	552	2773.232	1491.746
403	954.820	1031.448	453	299.430	952.101	503	1548.932	1156.979	553	2800.637	1498.916
404	929.979	1027.611	454	324.600	953.662	504	1574.732	1162.905	554	2828.265	1506.587
405	904.386	1023.126	455	350.549	955.781	505	1598.225	1168.160	555	2849.906	1514.083
406	878.162	1019.032	456	376.889	957.374	506	1622.070	1174.337	556	2877.363	1521.606
407	852.764	1015.012	457	400.611	960.273	507	1648.491	1180.674	557	2900.926	1528.903
408	829.477	1010.589	458	425.009	961.745	508	1672.676	1186.362	558	2922.933	1535.242
409	804.476	1007.059	459	451.156	964.632	509	1699.359	1192.925	559	2946.349	1542.711
410	777.100	1003.557	460	473.074	966.243	510	1721.478	1198.836	560	2973.590	1550.466
411	754.023	999.276	461	501.052	968.510	511	1748.692	1204.910	561	2995.885	1557.133
412	728.501	996.141	462	523.771	971.570	512	1772.717	1211.548	562	3023.058	1565.767
413	704.297	992.892	463	549.677	973.782	513	1799.002	1217.934	563	3047.187	1573.079
414	682.665	990.319	464	574.419	976.722	514	1824.082	1224.612	564	3072.056	1580.030
415	651.983	986.067	465	602.401	980.039	515	1846.130	1230.545	565	3097.786	1588.145
416	630.660	982.786	466	624.922	982.692	516	1873.676	1237.567	566	3123.280	1595.589
417	605.282	980.150	467	648.928	985.882	517	1898.386	1244.110	567	3147.799	1603.017
418	579.666	976.420	468	674.706	988.900	518	1922.128	1250.350	568	3173.841	1610.568
419	556.544	974.146	469	695.534	992.308	519	1946.425	1256.844	569	3197.658	1618.286
420	525.697	971.431	470	722.973	995.547	520	1972.733	1263.463	570	3224.520	1625.947
421	503.412	968.550	471	743.035	998.774	521	1995.992	1269.489	571	3246.308	1633.840
422	476.947	965.518	472	772.708	1002.640	522	2021.284	1276.605	572	3269.615	1641.181
423	456.543	963.432	473	799.365	1007.501	523	2047.768	1283.477	573	3298.234	1648.665
424	431.704	961.216	474	827.466	1010.404	524	2068.441	1289.092	574	3322.795	1656.675
425	405.669	959.313	475	847.578	1014.153	525	2099.202	1297.742	575	3348.757	1664.216
426	382.167	957.363	476	873.161	1017.853	526	2122.910	1304.563	576	3371.168	1670.785
427	360.032	955.795	477	898.705	1023.541	527	2146.801	1310.749	577	3397.601	1678.696
428	330.958	953.984	478	925.852	1026.076	528	2171.815	1314.782	578	3415.795	1685.196
429	310.206	952.081	479	947.130	1030.365	529	2200.140	1325.703	579	3448.241	1694.415
430	282.808	950.759	480	976.925	1036.107	530	2218.331	1331.626	580	3472.837	1701.577
431	260.541	949.642	481	993.203	1040.563	531	2249.944	1339.540	581	3498.606	1710.192
432	231.657	948.256	482	1023.519	1044.037	532	2272.620	1346.336	582	3522.813	1717.371
433	209.954	946.459	483	1052.331	1049.905	533	2294.818	1352.489	583	3549.675	1725.993
434	185.259	945.197	484	1074.363	1054.403	534	2323.298	1360.202	584	3572.790	1733.222
435	165.862	944.430	485	1098.092	1058.814	535	2348.619	1368.284	585	3596.293	1739.830
436	134.304	943.874	486	1124.219	1063.483	536	2373.838	1375.471	586	3624.682	1748.377
437	117.607	943.475	487	1149.317	1068.660	537	2397.572	1382.493	587	3649.510	1756.174
438	99.571	942.953	488	1174.603	1073.632	538	2423.962	1389.803	588	3674.382	1763.768
439	73.169	942.483	489	1196.443	1078.861	539	2448.348	1396.371	589	3696.833	1770.490
440	61.000	941.891	490	1223.741	1084.101	540	2472.638	1403.782	590	3725.141	1779.702
441	56.197	942.147	491	1247.658	1088.584	541	2497.266	1411.481	591	3748.488	1786.963
442	58.722	942.353	492	1272.022	1094.326	542	2524.872	1418.757	592	3773.125	1794.582
443	73.252	942.618	493	1297.550	1100.294	543	2548.532	1425.434	593	3797.180	1802.597
444	87.620	942.868	494	1321.672	1105.547	544	2571.795	1432.337	594	3823.886	1810.145
445	111.582	943.735	495	1347.028	1110.953	545	2596.858	1439.589	595	3847.157	1817.675
446	131.554	943.171	496	1376.170	1117.626	546	2621.377	1446.632	596	3873.904	1825.487
447	154.473	945.169	497	1396.418	1121.891	547	2644.413	1453.807	597	3899.011	1833.940
448	179.703	945.881	498	1422.895	1128.178	548	2674.605	1462.258	598	3924.745	1841.541
449	204.619	946.732	499	1443.884	1132.653	549	2702.929	1470.753	599	3947.236	1849.245
450	227.115	948.627	500	1467.463	1138.044	550	2723.228	1476.894	600	3974.137	1857.089

Table C.4: Traveltimes for Receiver 4.

Receiver Depth = 2003.758 m											
Source N.o.	Source Offset (m)	Traveltime (ms)	Source N.o.	Source Offset (m)	Traveltime (ms)	Source N.o.	Source Offset (m)	Traveltime (ms)	Source N.o.	Source Offset (m)	Traveltime (ms)
601	997.086	1042.833	651	253.949	953.203	701	1499.879	1148.672	751	2752.229	1487.699
602	972.731	1037.513	652	280.412	954.468	702	1527.695	1155.408	752	2778.230	1494.594
603	949.152	1033.673	653	303.261	956.100	703	1553.918	1161.119	753	2805.637	1502.098
604	924.305	1029.444	654	328.581	957.547	704	1579.704	1167.420	754	2833.270	1508.771
605	898.668	1025.462	655	354.657	959.877	705	1603.186	1172.206	755	2854.923	1516.733
606	872.462	1021.558	656	380.983	961.524	706	1627.036	1178.204	756	2882.394	1525.492
607	847.076	1017.731	657	404.849	964.467	707	1653.462	1184.507	757	2905.969	1531.940
608	823.748	1012.982	658	429.240	965.664	708	1677.641	1190.805	758	2927.986	1539.600
609	798.746	1009.341	659	455.469	968.875	709	1704.318	1197.292	759	2951.411	1546.765
610	771.348	1005.985	660	477.448	970.314	710	1726.445	1203.018	760	2978.669	1554.718
611	748.238	1002.028	661	505.381	972.350	711	1753.676	1209.147	761	3000.961	1561.351
612	722.703	999.005	662	528.180	975.954	712	1777.695	1215.748	762	3028.136	1568.134
613	698.475	995.761	663	554.124	977.649	713	1803.977	1221.607	763	3052.265	1577.714
614	676.858	993.036	664	578.871	980.507	714	1829.087	1228.617	764	3077.138	1582.686
615	646.129	988.844	665	606.897	984.222	715	1851.122	1234.195	765	3102.869	1590.615
616	624.840	985.924	666	629.448	987.011	716	1878.678	1241.198	766	3128.367	1599.738
617	599.449	983.380	667	653.514	990.246	717	1903.390	1247.676	767	3152.887	1606.000
618	573.811	979.481	668	679.317	993.458	718	1927.153	1254.113	768	3178.930	1613.464
619	550.684	977.140	669	700.261	996.693	719	1951.442	1260.869	769	3202.748	1619.519
620	519.689	974.557	670	727.683	1000.173	720	1977.755	1267.338	770	3229.613	1630.294
621	497.397	971.818	671	747.801	1003.167	721	2001.021	1273.069	771	3251.407	1636.149
622	470.942	969.121	672	777.454	1006.854	722	2026.319	1280.433	772	3274.706	1643.357
623	450.496	966.698	673	804.143	1011.369	723	2052.794	1287.490	773	3303.329	1649.475
624	425.642	964.633	674	832.193	1015.020	724	2073.482	1293.358	774	3327.898	1657.560
625	399.631	962.887	675	852.318	1018.689	725	2104.247	1301.024	775	3353.854	1664.552
626	376.026	960.981	676	877.902	1022.437	726	2127.948	1308.343	776	3376.264	1675.352
627	353.782	959.268	677	903.481	1027.936	727	2151.842	1314.503	777	3402.702	1680.203
628	324.691	957.854	678	930.585	1030.703	728	2176.867	1318.469	778	3420.895	1687.718
629	303.545	955.870	679	951.877	1035.000	729	2205.177	1329.099	779	3453.340	1698.745
630	275.979	954.239	680	981.685	1040.677	730	2223.370	1334.982	780	3477.933	1705.403
631	253.431	953.240	681	997.988	1045.077	731	2254.993	1342.631	781	3503.704	1711.605
632	224.502	952.059	682	1028.302	1048.441	732	2277.647	1350.118	782	3527.909	1720.754
633	202.690	950.595	683	1057.108	1054.518	733	2299.834	1357.171	783	3554.773	1729.231
634	177.711	949.141	684	1079.172	1058.712	734	2328.326	1364.622	784	3577.890	1735.458
635	157.906	948.403	685	1102.905	1063.161	735	2353.659	1371.613	785	3601.391	1744.448
636	126.487	948.019	686	1129.033	1067.551	736	2378.880	1379.627	786	3629.788	1751.149
637	108.628	947.600	687	1154.135	1072.604	737	2402.618	1386.764	787	3654.610	1760.526
638	89.868	947.095	688	1179.462	1077.918	738	2429.010	1393.956	788	3679.484	1768.197
639	62.742	946.545	689	1201.324	1083.181	739	2453.412	1400.834	789	3701.937	1775.120
640	50.086	945.980	690	1228.635	1088.640	740	2477.697	1407.589	790	3730.246	1782.591
641	46.358	946.538	691	1252.559	1092.830	741	2502.335	1415.158	791	3753.592	1790.948
642	52.469	946.447	692	1276.939	1098.534	742	2529.938	1422.226	792	3778.230	1798.312
643	69.671	946.954	693	1302.470	1104.879	743	2553.598	1429.520	793	3802.290	1804.984
644	86.893	947.101	694	1326.568	1109.972	744	2576.873	1436.827	794	3828.996	1813.300
645	112.734	947.711	695	1351.947	1115.153	745	2601.946	1443.173	795	3852.268	1823.626
646	133.464	947.722	696	1381.150	1121.642	746	2626.465	1450.736	796	3879.018	1828.743
647	156.651	949.129	697	1401.407	1126.247	747	2649.516	1458.285	797	3904.126	1835.432
648	182.453	949.660	698	1427.905	1132.330	748	2679.669	1465.704	798	3929.863	1845.600
649	207.535	950.746	699	1448.880	1136.977	749	2707.953	1474.176	799	3952.356	1852.445
650	230.490	952.851	700	1472.461	1142.246	750	2728.236	1480.744	800	3979.256	1857.067

Table C.5: Traveltimes for Receiver 5.

Receiver Depth = 2013.927 m											
Source N.o.	Source Offset (m)	Traveltime (ms)	Source N.o.	Source Offset (m)	Traveltime (ms)	Source N.o.	Source Offset (m)	Traveltime (ms)	Source N.o.	Source Offset (m)	Traveltime (ms)
801	991.550	1044.546	851	258.040	957.373	901	1504.896	1152.406	951	2757.260	1489.196
802	967.175	1039.433	852	284.557	958.386	902	1532.702	1159.518	952	2783.262	1497.292
803	943.576	1035.737	853	307.433	960.111	903	1558.966	1164.752	953	2810.670	1504.319
804	918.726	1031.620	854	332.872	961.630	904	1584.736	1170.728	954	2838.309	1512.353
805	893.046	1027.395	855	359.049	963.944	905	1608.206	1176.191	955	2859.972	1519.220
806	866.861	1023.883	856	385.343	965.418	906	1632.059	1182.031	956	2887.458	1526.834
807	841.491	1019.800	857	409.334	968.447	907	1658.491	1188.399	957	2911.043	1534.916
808	818.125	1015.300	858	433.705	969.921	908	1682.662	1193.896	958	2933.070	1540.726
809	793.125	1011.754	859	460.001	972.838	909	1709.332	1200.831	959	2956.504	1548.725
810	765.709	1008.324	860	482.029	974.457	910	1731.466	1206.627	960	2983.778	1555.046
811	742.569	1004.757	861	509.907	976.609	911	1758.713	1212.206	961	3006.069	1562.470
812	717.025	1001.513	862	532.777	979.967	912	1782.727	1218.930	962	3033.245	1570.417
813	692.777	998.272	863	558.748	981.933	913	1809.004	1224.991	963	3057.374	1578.054
814	671.179	995.647	864	583.493	985.107	914	1834.144	1232.119	964	3082.250	1585.655
815	640.407	991.688	865	611.554	988.531	915	1856.165	1237.956	965	3107.982	1593.522
816	619.158	988.858	866	634.129	991.086	916	1883.729	1244.659	966	3133.483	1600.080
817	593.758	986.490	867	658.248	994.422	917	1908.443	1250.987	967	3158.005	1608.654
818	568.106	982.274	868	684.072	997.434	918	1932.226	1257.720	968	3184.048	1615.445
819	544.979	980.074	869	705.124	1000.876	919	1956.508	1264.184	969	3207.868	1623.756
820	513.842	977.187	870	732.526	1004.018	920	1982.824	1270.513	970	3234.734	1630.595
821	491.551	974.652	871	752.696	1007.432	921	2006.097	1276.609	971	3256.536	1639.147
822	465.116	971.956	872	782.323	1011.254	922	2031.400	1283.866	972	3279.827	1646.444
823	444.635	970.103	873	809.041	1015.565	923	2057.867	1290.939	973	3308.451	1654.579
824	419.775	967.793	874	837.034	1019.073	924	2078.568	1296.333	974	3333.029	1662.212
825	393.803	966.024	875	857.170	1022.852	925	2109.336	1305.118	975	3358.978	1669.892
826	370.105	963.975	876	882.753	1026.294	926	2133.030	1311.261	976	3381.389	1674.585
827	347.762	962.375	877	908.363	1031.885	927	2156.926	1317.697	977	3407.830	1683.330
828	318.675	960.815	878	935.422	1034.363	928	2181.962	1322.426	978	3426.021	1689.103
829	297.136	959.260	879	956.725	1038.713	929	2210.257	1332.953	979	3458.467	1699.251
830	269.418	957.826	880	986.543	1044.700	930	2228.452	1338.401	980	3483.057	1707.174
831	246.599	956.764	881	1002.868	1049.014	931	2260.084	1346.712	981	3508.829	1714.270
832	217.658	955.323	882	1033.179	1052.495	932	2282.716	1353.271	982	3533.031	1721.476
833	195.765	953.803	883	1061.975	1058.421	933	2304.890	1359.676	983	3559.898	1730.402
834	170.528	952.296	884	1084.068	1062.677	934	2333.394	1367.060	984	3583.016	1738.836
835	150.322	951.830	885	1107.805	1066.960	935	2358.739	1375.573	985	3606.516	1744.451
836	119.158	951.246	886	1133.931	1071.377	936	2383.962	1382.318	986	3634.919	1752.517
837	100.035	951.140	887	1159.036	1076.518	937	2407.702	1389.120	987	3659.735	1760.693
838	80.477	950.595	888	1184.402	1081.816	938	2434.097	1396.500	988	3684.612	1767.779
839	52.512	950.060	889	1206.284	1087.232	939	2458.515	1403.233	989	3707.066	1774.926
840	39.174	949.748	890	1233.606	1092.486	940	2482.793	1410.509	990	3735.376	1785.556
841	37.125	949.931	891	1257.536	1096.881	941	2507.442	1418.106	991	3758.721	1792.247
842	47.917	949.852	892	1281.929	1102.535	942	2535.041	1425.056	992	3783.360	1799.150
843	67.679	950.437	893	1307.463	1108.661	943	2558.701	1432.211	993	3807.424	1805.479
844	87.531	950.647	894	1331.536	1113.833	944	2581.986	1439.055	994	3834.131	1814.840
845	114.917	951.544	895	1356.935	1119.047	945	2607.071	1445.480	995	3857.404	1823.009
846	136.226	951.374	896	1386.199	1125.490	946	2631.588	1452.599	996	3884.155	1829.612
847	159.548	953.025	897	1406.463	1130.003	947	2654.653	1459.835	997	3909.264	1837.849
848	185.804	953.865	898	1432.981	1136.112	948	2684.768	1469.199	998	3935.005	1845.303
849	210.975	954.950	899	1453.941	1141.041	949	2713.012	1477.709	999	3957.499	1852.544
850	234.325	956.605	900	1477.524	1145.902	950	2733.279	1482.503	1000	3984.399	1860.716

APPENDIX D

Synthetic Data

Computations for ray parameter, *p*, and traveltimes

The following equations were used for computations.

Original expression (1.2):

$$t=\frac{1}{b}\ln\left[\frac{a+bz}{a}\frac{1+\sqrt{1-p^2a^2(1+2\chi)}}{1+\sqrt{1-p^2(a+bz)^2(1+2\chi)}}\right].$$

Reformulated expression (1.3):

$$t=\frac{1}{2b}\left[\ln\frac{1-\sqrt{1-p^2a^2(1+2\chi)}+pbX}{1+\sqrt{1-p^2a^2(1+2\chi)}-pbX}-\ln\frac{1-\sqrt{1-p^2a^2(1+2\chi)}}{1+\sqrt{1-p^2a^2(1+2\chi)}}\right].$$

Expression (1.36) to obtain the ray parameter, *p*:

$$p=\frac{2X}{\sqrt{\left[X^2+(1+2\chi)Z^2\right]\left[(2a+bZ)^2(1+2\chi)+b^2X^2\right]}}.$$

Table D.1: Ray parameter p and traveltimes for synthetic zero-offset data. $a = 1350.1624$ m/s and $b = 0.884$ /s. $\chi = 0$.

Depth z (m)	Offset x (m)	Ray parameter p	Traveltime using original expression (1.2) (ms)	Traveltime using reformulated expression (1.3) (ms)
1.000	1.000	0.000523548	1.047097	1.047097
100.000	1.000	0.000007171	71.744968	71.744968
200.000	1.000	0.000003476	139.204741	139.204741
300.000	1.000	0.000002248	202.867987	202.867987
400.000	1.000	0.000001637	263.138681	263.138681
500.000	1.000	0.000001273	320.360047	320.360047
600.000	1.000	0.000001032	374.825796	374.825796
700.000	1.000	0.000000861	426.789168	426.789168
800.000	1.000	0.000000734	476.470029	476.470029
900.000	1.000	0.000000636	524.060488	524.060488
1000.000	1.000	0.000000558	569.729374	569.729374
1100.000	1.000	0.000000495	613.625860	613.625860
1200.000	1.000	0.000000443	655.882392	655.882393
1300.000	1.000	0.000000400	696.617107	696.617107
1400.000	1.000	0.000000363	735.935816	735.935816
1500.000	1.000	0.000000331	773.933666	773.933667
1600.000	1.000	0.000000304	810.696526	810.696526
1700.000	1.000	0.000000280	846.302153	846.302153
1800.000	1.000	0.000000259	880.821184	880.821184
1900.000	1.000	0.000000240	914.317980	914.317981
2000.000	1.000	0.000000224	946.851349	946.851349
$a =$ 1350.1624		$b =$ 0.8840		

Table D.2: Ray parameter p and traveltime calculations for synthetic offset data. a = 1350.1624 m/s and b = 0.884 /s. $\chi = 0$.

Depth z (m)	Offset x (m)	Ray parameter p	Traveltime using original expression (1.2) (ms)	Traveltime using reformulated expression (1.3) (ms)
1960.000	900.000	0.00018531	1022.030112	1022.030112
1960.000	1000.000	0.00020108	1041.359390	1041.359390
1960.000	1100.000	0.00021568	1062.207268	1062.207268
1960.000	1200.000	0.00022911	1084.456357	1084.456357
1960.000	1300.000	0.00024140	1107.990997	1107.990997
1960.000	1400.000	0.00025258	1132.698629	1132.698629
1960.000	1500.000	0.00026270	1158.470841	1158.470841
1960.000	1600.000	0.00027181	1185.204118	1185.204118
1960.000	1700.000	0.00027996	1212.800355	1212.800355
1960.000	1800.000	0.00028723	1241.167151	1241.167151
1960.000	1900.000	0.00029365	1270.217937	1270.217937
1960.000	2000.000	0.00029930	1299.871972	1299.871972
1960.000	2100.000	0.00030423	1330.054235	1330.054235
1960.000	2200.000	0.00030849	1360.695243	1360.695243
1960.000	2300.000	0.00031213	1391.730826	1391.730826
1960.000	2400.000	0.00031520	1423.101855	1423.101855
1960.000	2500.000	0.00031776	1454.753962	1454.753962
1960.000	2600.000	0.00031983	1486.637246	1486.637246
1960.000	2700.000	0.00032147	1518.705980	1518.70598
1970.000	900.000	0.00018417	1024.690802	1024.690802
1970.000	1000.000	0.00019989	1043.903554	1043.903554
1970.000	1100.000	0.00021444	1064.629493	1064.629493
1970.000	1200.000	0.00022783	1086.752508	1086.752508
1970.000	1300.000	0.00024009	1110.158108	1110.158108
1970.000	1400.000	0.00025126	1134.734782	1134.734782
1970.000	1500.000	0.00026137	1160.375038	1160.375038
1970.000	1600.000	0.00027049	1186.976165	1186.976165
1970.000	1700.000	0.00027865	1214.440743	1214.440743
1970.000	1800.000	0.00028593	1242.676950	1242.67695
1970.000	1900.000	0.00029237	1271.598699	1271.598699
1970.000	2000.000	0.00029804	1301.125644	1301.125644
1970.000	2100.000	0.00030299	1331.183081	1331.183081
1970.000	2200.000	0.00030728	1361.701782	1361.701782
1970.000	2300.000	0.00031095	1392.617768	1392.617768
1970.000	2400.000	0.00031405	1423.872057	1423.872057
1970.000	2500.000	0.00031663	1455.410384	1455.410384
1970.000	2600.000	0.00031874	1487.182916	1487.182916
1970.000	2700.000	0.00032041	1519.143966	1519.143966
1980.000	900.000	0.00018305	1027.348060	1027.34806
1980.000	1000.000	0.00019870	1046.445303	1046.445303
1980.000	1100.000	0.00021321	1067.050318	1067.050318
1980.000	1200.000	0.00022656	1089.048257	1089.048257
1980.000	1300.000	0.00023880	1112.325784	1112.325784
1980.000	1400.000	0.00024995	1136.772426	1136.772426
1980.000	1500.000	0.00026006	1162.281608	1162.281608
1980.000	1600.000	0.00026917	1188.751416	1188.751416
1980.000	1700.000	0.00027735	1216.085115	1216.085115
1980.000	1800.000	0.00028464	1244.191459	1244.191459
1980.000	1900.000	0.00029110	1272.984846	1272.984846
1980.000	2000.000	0.00029679	1302.385324	1302.385324
1980.000	2100.000	0.00030176	1332.318510	1332.31851
1980.000	2200.000	0.00030607	1362.715430	1362.71543
1980.000	2300.000	0.00030977	1393.512303	1393.512303
1980.000	2400.000	0.00031290	1424.650294	1424.650294
1980.000	2500.000	0.00031551	1456.075243	1456.075243
1980.000	2600.000	0.00031765	1487.737391	1487.737391
1980.000	2700.000	0.00031935	1519.591090	1519.59109

Depth z (m)	Offset x (m)	Ray parameter p	Traveltime using original expression (1.2) (ms)	Traveltime using reformulated expression (1.3) (ms)
1990.000	900.000	0.00018194	1030.001859	1030.001859
1990.000	1000.000	0.00019753	1048.984602	1048.984602
1990.000	1100.000	0.00021198	1069.469698	1069.469698
1990.000	1200.000	0.00022531	1091.343548	1091.343548
1990.000	1300.000	0.00023752	1114.493960	1114.49396
1990.000	1400.000	0.00024866	1138.811491	1138.811491
1990.000	1500.000	0.00025876	1164.190474	1164.190474
1990.000	1600.000	0.00026787	1190.529791	1190.529791
1990.000	1700.000	0.00027605	1217.733385	1217.733385
1990.000	1800.000	0.00028335	1245.710592	1245.710592
1990.000	1900.000	0.00028983	1274.376288	1274.376288
1990.000	2000.000	0.00029554	1303.650921	1303.650921
1990.000	2100.000	0.00030054	1333.460430	1333.46043
1990.000	2200.000	0.00030487	1363.736096	1363.736096
1990.000	2300.000	0.00030860	1394.414338	1394.414338
1990.000	2400.000	0.00031176	1425.436472	1425.436472
1990.000	2500.000	0.00031440	1456.748447	1456.748447
1990.000	2600.000	0.00031657	1488.300577	1488.300577
1990.000	2700.000	0.00031830	1520.047259	1520.047259
2000.000	900.000	0.00018083	1032.652174	1032.652174
2000.000	1000.000	0.00019636	1051.521414	1051.521414
2000.000	1100.000	0.00021077	1071.887587	1071.887587
2000.000	1200.000	0.00022406	1093.638326	1093.638326
2000.000	1300.000	0.00023625	1116.662574	1116.662574
2000.000	1400.000	0.00024737	1140.851907	1140.851907
2000.000	1500.000	0.00025746	1166.101562	1166.101562
2000.000	1600.000	0.00026657	1192.311208	1192.311208
2000.000	1700.000	0.00027476	1219.385471	1219.385471
2000.000	1800.000	0.00028207	1247.234260	1247.23426
2000.000	1900.000	0.00028857	1275.772936	1275.772936
2000.000	2000.000	0.00029430	1304.922344	1304.922344
2000.000	2100.000	0.00029932	1334.608748	1334.608748
2000.000	2200.000	0.00030368	1364.763686	1364.763686
2000.000	2300.000	0.00030743	1395.323781	1395.323781
2000.000	2400.000	0.00031062	1426.230499	1426.230499
2000.000	2500.000	0.00031329	1457.429904	1457.429904
2000.000	2600.000	0.00031549	1488.872383	1488.872383
2000.000	2700.000	0.00031725	1520.512383	1520.512383
a	1350.1624	b	0.8840	

Table D.3: Ray parameter p and traveltime calculations for synthetic offset data. $a = 2000$ m/s, $b = 0.88$/s. $\chi = 0$.

Depth z (m)	Offset x (m)	Ray parameter p	Traveltime using original expression (1.2) (ms)	Traveltime using reformulated expression (1.3) (ms)
1960.000	900.000	0.00014441	775.083667	775.083667
1960.000	1000.000	0.00015693	790.157754	790.157754
1960.000	1100.000	0.00016859	806.440785	806.440785
1960.000	1200.000	0.00017939	823.846835	823.846835
1960.000	1300.000	0.00018936	842.291228	842.291228
1960.000	1400.000	0.00019851	861.691526	861.691526
1960.000	1500.000	0.00020689	881.968278	881.968278
1960.000	1600.000	0.00021453	903.045562	903.045562
1960.000	1700.000	0.00022147	924.851336	924.851336
1960.000	1800.000	0.00022775	947.317647	947.317647
1960.000	1900.000	0.00023341	970.380708	970.380708
1960.000	2000.000	0.00023850	993.980889	993.980889
1960.000	2100.000	0.00024305	1018.062624	1018.062624
1960.000	2200.000	0.00024710	1042.574277	1042.574277
1960.000	2300.000	0.00025070	1067.467971	1067.467971
1960.000	2400.000	0.00025386	1092.699386	1092.699386
1960.000	2500.000	0.00025664	1118.227556	1118.227556
1960.000	2600.000	0.00025905	1144.014656	1144.014656
1960.000	2700.000	0.00026112	1170.025787	1170.025787
1970.000	900.000	0.00014359	777.345779	777.345779
1970.000	1000.000	0.00015606	792.335274	792.335274
1970.000	1100.000	0.00016769	808.529729	808.529729
1970.000	1200.000	0.00017846	825.844129	825.844129
1970.000	1300.000	0.00018841	844.194629	844.194629
1970.000	1400.000	0.00019756	863.499531	863.499531
1970.000	1500.000	0.00020593	883.680038	883.680038
1970.000	1600.000	0.00021357	904.660790	904.660790
1970.000	1700.000	0.00022051	926.370228	926.370228
1970.000	1800.000	0.00022680	948.740802	948.740802
1970.000	1900.000	0.00023247	971.709063	971.709063
1970.000	2000.000	0.00023757	995.215653	995.215653
1970.000	2100.000	0.00024214	1019.205227	1019.205227
1970.000	2200.000	0.00024621	1043.626326	1043.626326
1970.000	2300.000	0.00024982	1068.431203	1068.431203
1970.000	2400.000	0.00025300	1093.575642	1093.575642
1970.000	2500.000	0.00025580	1119.018748	1119.018748
1970.000	2600.000	0.00025823	1144.722744	1144.722744
1970.000	2700.000	0.00026032	1170.652763	1170.652763
1980.000	900.000	0.00014277	779.605615	779.605615
1980.000	1000.000	0.00015520	794.511220	794.511220
1980.000	1100.000	0.00016679	810.617796	810.617796
1980.000	1200.000	0.00017754	827.841229	827.841229
1980.000	1300.000	0.00018747	846.098495	846.098495
1980.000	1400.000	0.00019660	865.308632	865.308632
1980.000	1500.000	0.00020497	885.393491	885.393491
1980.000	1600.000	0.00021261	906.278273	906.278273
1980.000	1700.000	0.00021955	927.891900	927.891900
1980.000	1800.000	0.00022585	950.167226	950.167226
1980.000	1900.000	0.00023153	973.041138	973.041138
1980.000	2000.000	0.00023664	996.454553	996.454553
1980.000	2100.000	0.00024123	1020.352351	1020.352351
1980.000	2200.000	0.00024531	1044.683245	1044.683245
1980.000	2300.000	0.00024894	1069.399628	1069.399628
1980.000	2400.000	0.00025215	1094.457384	1094.457384
1980.000	2500.000	0.00025496	1119.815694	1119.815694
1980.000	2600.000	0.00025741	1145.436831	1145.436831
1980.000	2700.000	0.00025952	1171.285959	1171.285959

Depth z (m)	Offset x (m)	Ray parameter p	Traveltime using original expression (1.2) (ms)	Traveltime using reformulated expression (1.3) (ms)
1990.000	900.000	0.00014196	781.863152	781.863152
1990.000	1000.000	0.00015435	796.685562	796.685562
1990.000	1100.000	0.00016590	812.704950	812.704950
1990.000	1200.000	0.00017662	829.838092	829.838092
1990.000	1300.000	0.00018654	848.002778	848.002778
1990.000	1400.000	0.00019566	867.118777	867.118777
1990.000	1500.000	0.00020402	887.108581	887.108581
1990.000	1600.000	0.00021165	907.897953	907.897953
1990.000	1700.000	0.00021860	929.416291	929.416291
1990.000	1800.000	0.00022490	951.596856	951.596856
1990.000	1900.000	0.00023060	974.376870	974.376870
1990.000	2000.000	0.00023572	997.697528	997.697528
1990.000	2100.000	0.00024032	1021.503931	1021.503931
1990.000	2200.000	0.00024442	1045.744972	1045.744972
1990.000	2300.000	0.00024807	1070.373181	1070.373181
1990.000	2400.000	0.00025129	1095.344549	1095.344549
1990.000	2500.000	0.00025412	1120.618331	1120.618331
1990.000	2600.000	0.00025659	1146.156854	1146.156854
1990.000	2700.000	0.00025873	1171.925314	1171.925314
2000.000	900.000	0.00014116	784.118369	784.118369
2000.000	1000.000	0.00015350	798.858270	798.858270
2000.000	1100.000	0.00016502	814.791154	814.791154
2000.000	1200.000	0.00017572	831.834675	831.834675
2000.000	1300.000	0.00018561	849.907431	849.907431
2000.000	1400.000	0.00019471	868.929913	868.929913
2000.000	1500.000	0.00020307	888.825255	888.825255
2000.000	1600.000	0.00021070	909.519773	909.519773
2000.000	1700.000	0.00021766	930.943344	930.943344
2000.000	1800.000	0.00022397	953.029633	953.029633
2000.000	1900.000	0.00022967	975.716199	975.716199
2000.000	2000.000	0.00023481	998.944513	998.944513
2000.000	2100.000	0.00023942	1022.659905	1022.659905
2000.000	2200.000	0.00024354	1046.811444	1046.811444
2000.000	2300.000	0.00024720	1071.351802	1071.351802
2000.000	2400.000	0.00025044	1096.237075	1096.237075
2000.000	2500.000	0.00025329	1121.426599	1121.426599
2000.000	2600.000	0.00025578	1146.882753	1146.882753
2000.000	2700.000	0.00025793	1172.570769	1172.570769

a = 2000.0000 b = 0.8800

Table D.4: Ray parameter p and traveltime calculations for synthetic offset data. Introduction of insignificant χ, $a = 2000$ m/s, $b = 0.880$ /s and $\chi = 0.0001$.

Depth z (m)	Offset x (m)	Ray parameter p	Traveltime using original expression (1.2) (ms)	Traveltime using reformulated expression (1.3) (ms)
1960.000	900.000	0.000144	775.070673	775.070673
1960.000	1000.000	0.00015690	790.142064	790.142064
1960.000	1100.000	0.00016856	806.422244	806.422244
1960.000	1200.000	0.00017936	823.825312	823.825312
1960.000	1300.000	0.00018933	842.266616	842.266616
1960.000	1400.000	0.00019848	861.663739	861.663739
1960.000	1500.000	0.00020686	881.937250	881.937250
1960.000	1600.000	0.00021450	903.011243	903.011243
1960.000	1700.000	0.00022144	924.813692	924.813692
1960.000	1800.000	0.00022772	947.276659	947.276659
1960.000	1900.000	0.00023338	970.336368	970.336368
1960.000	2000.000	0.00023847	993.933197	993.933197
1960.000	2100.000	0.00024302	1018.011592	1018.011592
1960.000	2200.000	0.00024707	1042.519923	1042.519923
1960.000	2300.000	0.00025066	1067.410320	1067.410320
1960.000	2400.000	0.00025383	1092.638469	1092.638469
1960.000	2500.000	0.00025660	1118.163407	1118.163407
1960.000	2600.000	0.00025902	1143.947314	1143.947314
1960.000	2700.000	0.00026109	1169.955296	1169.955296
1970.000	900.000	0.00014356	777.332859	777.332859
1970.000	1000.000	0.00015603	792.319671	792.319671
1970.000	1100.000	0.00016766	808.511287	808.511287
1970.000	1200.000	0.00017843	825.822718	825.822718
1970.000	1300.000	0.00018838	844.170140	844.170140
1970.000	1400.000	0.00019752	863.471879	863.471879
1970.000	1500.000	0.00020590	883.649154	883.649154
1970.000	1600.000	0.00021353	904.626625	904.626625
1970.000	1700.000	0.00022048	926.332748	926.332748
1970.000	1800.000	0.00022676	948.699986	948.699986
1970.000	1900.000	0.00023244	971.664901	971.664901
1970.000	2000.000	0.00023754	995.168147	995.168147
1970.000	2100.000	0.00024210	1019.154387	1019.154387
1970.000	2200.000	0.00024617	1043.572169	1043.572169
1970.000	2300.000	0.00024978	1068.373755	1068.373755
1970.000	2400.000	0.00025297	1093.514931	1093.514931
1970.000	2500.000	0.00025576	1118.954809	1118.954809
1970.000	2600.000	0.00025819	1144.655617	1144.655617
1970.000	2700.000	0.00026029	1170.582488	1170.582488
1980.000	900.000	0.00014274	779.592768	779.592768
1980.000	1000.000	0.00015517	794.495703	794.495703
1980.000	1100.000	0.00016676	810.599453	810.599453
1980.000	1200.000	0.00017751	827.819928	827.819928
1980.000	1300.000	0.00018744	846.074128	846.074128
1980.000	1400.000	0.00019657	865.281113	865.281113
1980.000	1500.000	0.00020494	885.362751	885.362751
1980.000	1600.000	0.00021257	906.244262	906.244262
1980.000	1700.000	0.00021952	927.854582	927.854582
1980.000	1800.000	0.00022581	950.126580	950.126580
1980.000	1900.000	0.00023150	972.997154	972.997154
1980.000	2000.000	0.00023661	996.407233	996.407233
1980.000	2100.000	0.00024119	1020.301702	1020.301702
1980.000	2200.000	0.00024528	1044.629285	1044.629285
1980.000	2300.000	0.00024891	1069.342381	1069.342381
1980.000	2400.000	0.00025211	1094.396879	1094.396879
1980.000	2500.000	0.00025493	1119.751965	1119.751965
1980.000	2600.000	0.00025738	1145.369916	1145.369916
1980.000	2700.000	0.00025949	1171.215899	1171.215899
1990.000	900.000	0.00014194	781.850378	781.850378
1990.000	1000.000	0.00015432	796.670130	796.670130
1990.000	1100.000	0.00016587	812.686704	812.686704
1990.000	1200.000	0.00017659	829.816901	829.816901
1990.000	1300.000	0.00018650	847.978533	847.978533
1990.000	1400.000	0.00019562	867.091390	867.091390
1990.000	1500.000	0.00020398	887.077984	887.077984
1990.000	1600.000	0.00021162	907.864095	907.864095
1990.000	1700.000	0.00021857	929.379136	929.379136
1990.000	1800.000	0.00022487	951.556381	951.556381
1990.000	1900.000	0.00023056	974.333064	974.333064
1990.000	2000.000	0.00023569	997.650391	997.650391
1990.000	2100.000	0.00024029	1021.453472	1021.453472
1990.000	2200.000	0.00024439	1045.691208	1045.691208
1990.000	2300.000	0.00024804	1070.316135	1070.316135
1990.000	2400.000	0.00025126	1095.284249	1095.284249
1990.000	2500.000	0.00025409	1120.554811	1120.554811
1990.000	2600.000	0.00025656	1146.090151	1146.090151
1990.000	2700.000	0.00025869	1171.855469	1171.855469
2000.000	900.000	0.00014113	784.105667	784.105667
2000.000	1000.000	0.00015347	798.842923	798.842923
2000.000	1100.000	0.00016499	814.773005	814.773005
2000.000	1200.000	0.00017569	831.813593	831.813593
2000.000	1300.000	0.00018558	849.883307	849.883307
2000.000	1400.000	0.00019468	868.902658	868.902658
2000.000	1500.000	0.00020304	888.794800	888.794800
2000.000	1600.000	0.00021067	909.486066	909.486066
2000.000	1700.000	0.00021762	930.906349	930.906349
2000.000	1800.000	0.00022393	952.989326	952.989326
2000.000	1900.000	0.00022964	975.672569	975.672569
2000.000	2000.000	0.00023477	998.897560	998.897560
2000.000	2100.000	0.00023938	1022.609636	1022.609636
2000.000	2200.000	0.00024350	1046.757875	1046.757875
2000.000	2300.000	0.00024717	1071.294956	1071.294956
2000.000	2400.000	0.00025041	1096.176980	1096.176980
2000.000	2500.000	0.00025326	1121.363287	1121.363287
2000.000	2600.000	0.00025574	1146.816262	1146.816262
2000.000	2700.000	0.00025790	1172.501139	1172.501139

a = 2000.0000 b = 0.8800 χ = 0.0001000

Table D.5: Ray parameter p and traveltime calculations for synthetic offset data. Introduction of significant χ, a = 2000 m/s, b = 0.880 /s and χ = 0.2.

Depth z (m)	Offset x (m)	Ray parameter p	Traveltime using original expression (1.2) (ms)	Traveltime using reformulated expression (1.3) (ms)
1960.000	900.000	0.00010610	756.254532	756.254532
1960.000	1000.000	0.00011594	767.360570	767.360570
1960.000	1100.000	0.00012526	779.424862	779.424862
1960.000	1200.000	0.00013407	792.395934	792.395934
1960.000	1300.000	0.00014236	806.221805	806.221805
1960.000	1400.000	0.00015013	820.850604	820.850604
1960.000	1500.000	0.00015740	836.231098	836.231098
1960.000	1600.000	0.00016416	852.313124	852.313124
1960.000	1700.000	0.00017045	869.047939	869.047939
1960.000	1800.000	0.00017628	886.388485	886.388485
1960.000	1900.000	0.00018167	904.289583	904.289583
1960.000	2000.000	0.00018663	922.708070	922.708070
1960.000	2100.000	0.00019120	941.602871	941.602871
1960.000	2200.000	0.00019538	960.935042	960.935042
1960.000	2300.000	0.00019921	980.667764	980.667764
1960.000	2400.000	0.00020270	1000.766315	1000.766315
1960.000	2500.000	0.00020588	1021.198024	1021.198024
1960.000	2600.000	0.00020876	1041.932200	1041.932200
1960.000	2700.000	0.00021136	1062.940056	1062.940056
1970.000	900.000	0.00010547	758.626027	758.626027
1970.000	1000.000	0.00011527	769.667033	769.667033
1970.000	1100.000	0.00012456	781.662348	781.662348
1970.000	1200.000	0.00013333	794.561110	794.561110
1970.000	1300.000	0.00014160	808.311922	808.311922
1970.000	1400.000	0.00014935	822.863460	822.863460
1970.000	1500.000	0.00015660	838.164995	838.164995
1970.000	1600.000	0.00016336	854.166828	854.166828
1970.000	1700.000	0.00016964	870.820630	870.820630
1970.000	1800.000	0.00017547	888.079711	888.079711
1970.000	1900.000	0.00018085	905.899221	905.899221
1970.000	2000.000	0.00018582	924.236278	924.236278
1970.000	2100.000	0.00019039	943.050053	943.050053
1970.000	2200.000	0.00019458	962.301812	962.301812
1970.000	2300.000	0.00019842	981.954911	981.954911
1970.000	2400.000	0.00020192	1001.974779	1001.974779
1970.000	2500.000	0.00020511	1022.328866	1022.328866
1970.000	2600.000	0.00020800	1042.986580	1042.986580
1970.000	2700.000	0.00021061	1063.919216	1063.919216
1980.000	900.000	0.00010485	760.994284	760.994284
1980.000	1000.000	0.00011460	771.970838	771.970838
1980.000	1100.000	0.00012385	783.897766	783.897766
1980.000	1200.000	0.00013260	796.724812	796.724812
1980.000	1300.000	0.00014084	810.401153	810.401153
1980.000	1400.000	0.00014857	824.876007	824.876007
1980.000	1500.000	0.00015581	840.099148	840.099148
1980.000	1600.000	0.00016256	856.021330	856.021330
1980.000	1700.000	0.00016883	872.594639	872.594639
1980.000	1800.000	0.00017466	889.772753	889.772753
1980.000	1900.000	0.00018004	907.511145	907.511145
1980.000	2000.000	0.00018501	925.767216	925.767216
1980.000	2100.000	0.00018959	944.500384	944.500384
1980.000	2200.000	0.00019379	963.672122	963.672122
1980.000	2300.000	0.00019763	983.245966	983.245966
1980.000	2400.000	0.00020114	1003.187492	1003.187492
1980.000	2500.000	0.00020434	1023.464274	1023.464274
1980.000	2600.000	0.00020724	1044.045823	1044.045823
1980.000	2700.000	0.00020987	1064.903512	1064.903512

Depth z (m)	Offset x (m)	Ray parameter p	Traveltime using original expression (1.2) (ms)	Traveltime using reformulated expression (1.3) (ms)
1990.000	900.000	0.00010423	763.359293	763.359293
1990.000	1000.000	0.00011394	774.271966	774.271966
1990.000	1100.000	0.00012316	786.131092	786.131092
1990.000	1200.000	0.00013188	798.887008	798.887008
1990.000	1300.000	0.00014009	812.489461	812.489461
1990.000	1400.000	0.00014780	826.888205	826.888205
1990.000	1500.000	0.00015502	842.033509	842.033509
1990.000	1600.000	0.00016176	857.876581	857.876581
1990.000	1700.000	0.00016803	874.369915	874.369915
1990.000	1800.000	0.00017385	891.467555	891.467555
1990.000	1900.000	0.00017924	909.125297	909.125297
1990.000	2000.000	0.00018421	927.300826	927.300826
1990.000	2100.000	0.00018879	945.953803	945.953803
1990.000	2200.000	0.00019299	965.045911	965.045911
1990.000	2300.000	0.00019685	984.540865	984.540865
1990.000	2400.000	0.00020037	1004.404391	1004.404391
1990.000	2500.000	0.00020358	1024.604186	1024.604186
1990.000	2600.000	0.00020649	1045.109864	1045.109864
1990.000	2700.000	0.00020913	1065.892881	1065.892881
2000.000	900.000	0.00010362	765.721041	765.721041
2000.000	1000.000	0.00011329	776.570400	776.570400
2000.000	1100.000	0.00012247	788.362300	788.362300
2000.000	1200.000	0.00013116	801.047667	801.047667
2000.000	1300.000	0.00013934	814.576810	814.576810
2000.000	1400.000	0.00014704	828.900013	828.900013
2000.000	1500.000	0.00015424	843.968033	843.968033
2000.000	1600.000	0.00016097	859.732530	859.732530
2000.000	1700.000	0.00016723	876.146404	876.146404
2000.000	1800.000	0.00017305	893.164061	893.164061
2000.000	1900.000	0.00017843	910.741621	910.741621
2000.000	2000.000	0.00018341	928.837048	928.837048
2000.000	2100.000	0.00018799	947.410249	947.410249
2000.000	2200.000	0.00019221	966.423117	966.423117
2000.000	2300.000	0.00019607	985.839546	985.839546
2000.000	2400.000	0.00019960	1005.625412	1005.625412
2000.000	2500.000	0.00020282	1025.748539	1025.748539
2000.000	2600.000	0.00020574	1046.178642	1046.178642
2000.000	2700.000	0.00020839	1066.887261	1066.887261
a = 2000.0000		b = 0.8800		χ = 0.2000

APPENDIX E

Real Data: Offset

Isotropic Cases: Inverse results for a, b, with $\chi = 0$

Anisotropic Cases: Inverse results for a, b, and χ

Table E.1: *a*, *b*, and $\chi = 0$, with maximum offsets increasing from 47.9 m to 3984.4 m, for all receivers, includes the longside and shortside, (A+B+C). Best values (minimum standard error) are highlighted.

Max Offset (m)	# observations	*a*	Standard Error	*b*	Standard Error	Max Offset (m)	# observations	*a*	Standard Error	*b*	Standard Error
47.92	19	1665.84	28.778	0.4893	0.03398	2047.77	613	1077.89	2.268	1.2999	0.00349
99.57	33	1654.28	17.564	0.5028	0.02088	2073.48	619	1078.62	2.205	1.2988	0.00339
119.62	44	1661.06	14.674	0.4947	0.01739	2099.20	623	1078.92	2.160	1.2983	0.00331
142.49	54	1660.06	16.201	0.4960	0.01922	2122.91	628	1079.57	2.110	1.2973	0.00323
174.10	65	1652.94	16.406	0.5046	0.01952	2146.80	633	1080.44	2.063	1.2959	0.00315
195.77	75	1657.14	15.691	0.4996	0.01863	2171.82	638	1080.15	2.031	1.2964	0.00310
224.50	88	1664.87	14.822	0.4905	0.01754	2195.22	642	1080.41	1.988	1.2960	0.00303
247.11	98	1673.08	14.056	0.4808	0.01658	2223.37	649	1082.33	1.940	1.2930	0.00294
273.34	107	1674.49	13.396	0.4791	0.01579	2249.94	653	1083.07	1.912	1.2918	0.00290
299.43	119	1668.35	12.970	0.4865	0.01533	2272.62	658	1084.47	1.880	1.2896	0.00284
324.69	130	1666.61	12.936	0.4887	0.01530	2299.83	664	1086.39	1.854	1.2866	0.00279
347.76	138	1659.12	12.830	0.4976	0.01522	2323.30	668	1087.31	1.831	1.2852	0.00275
373.16	148	1656.23	13.542	0.5012	0.01608	2348.62	673	1088.85	1.808	1.2828	0.00271
399.63	159	1644.04	14.341	0.5159	0.01712	2373.84	678	1090.46	1.792	1.2803	0.00268
421.11	168	1643.13	14.971	0.5171	0.01787	2397.57	683	1092.23	1.780	1.2775	0.00265
447.16	178	1630.54	16.272	0.5323	0.01953	2423.96	688	1093.99	1.769	1.2748	0.00263
473.07	190	1615.42	17.577	0.5507	0.02124	2448.35	693	1095.44	1.753	1.2726	0.00260
497.40	199	1603.17	19.059	0.5658	0.02315	2472.64	698	1096.96	1.739	1.2702	0.00257
523.77	210	1579.93	19.828	0.5944	0.02433	2497.27	703	1098.65	1.730	1.2676	0.00255
549.68	219	1564.36	20.370	0.6137	0.02517	2524.87	708	1100.26	1.721	1.2652	0.00253
574.42	230	1520.57	21.733	0.6687	0.02740	2548.53	713	1101.87	1.708	1.2627	0.00250
599.45	239	1492.65	22.186	0.7043	0.02834	2571.80	718	1103.39	1.697	1.2604	0.00248
624.92	250	1450.70	21.976	0.7587	0.02865	2596.86	723	1104.92	1.688	1.2581	0.00246
648.93	260	1412.84	21.473	0.8087	0.02853	2621.38	728	1106.30	1.674	1.2559	0.00243
674.71	269	1381.41	20.977	0.8510	0.02832	2649.52	734	1108.45	1.672	1.2527	0.00242
698.48	280	1343.86	19.646	0.9024	0.02705	2674.60	738	1109.58	1.661	1.2510	0.00239
722.97	290	1312.83	18.671	0.9457	0.02615	2698.02	742	1110.99	1.660	1.2488	0.00239
748.24	301	1281.28	17.346	0.9905	0.02472	2723.23	748	1112.93	1.653	1.2459	0.00237
772.71	310	1255.69	16.593	1.0274	0.02399	2747.23	753	1118.02	1.285	1.2385	0.00182
799.36	320	1231.35	15.503	1.0630	0.02273	2773.23	758	1127.74	1.244	1.2245	0.00175
823.75	329	1209.00	14.746	1.0962	0.02191	2795.75	762	1135.23	1.247	1.2138	0.00174
847.58	340	1186.16	13.764	1.1305	0.02072	2823.37	767	1147.06	1.234	1.1971	0.00169
873.16	350	1172.17	12.920	1.1518	0.01961	2849.91	773	1160.98	1.226	1.1776	0.00165
898.70	360	1160.80	12.022	1.1692	0.01837	2872.44	777	1170.34	1.296	1.1646	0.00173
924.31	369	1149.69	11.491	1.1864	0.01767	2895.99	782	1182.57	1.399	1.1478	0.00184
949.15	380	1134.32	10.699	1.2103	0.01661	2922.93	788	1196.67	1.460	1.1286	0.00189
972.73	389	1124.84	10.120	1.2252	0.01580	2946.35	793	1207.64	1.509	1.1138	0.00193
997.99	401	1120.93	9.456	1.2314	0.01478	2973.59	798	1219.31	1.599	1.0982	0.00202
1023.52	408	1114.82	9.192	1.2410	0.01442	2995.88	803	1231.00	1.682	1.0827	0.00210
1047.73	412	1112.53	8.966	1.2446	0.01408	3023.06	808	1243.55	1.804	1.0663	0.00223
1074.36	418	1110.38	8.607	1.2480	0.01353	3047.19	813	1254.84	1.837	1.0516	0.00223
1098.09	423	1108.38	8.332	1.2512	0.01311	3072.06	818	1265.98	1.875	1.0372	0.00225
1124.22	428	1105.23	8.065	1.2562	0.01271	3097.79	823	1278.39	1.978	1.0214	0.00235
1149.32	433	1101.63	7.776	1.2620	0.01227	3123.28	828	1290.09	2.034	1.0066	0.00238
1174.60	438	1098.42	7.492	1.2671	0.01184	3147.80	833	1300.92	2.061	0.9930	0.00238
1196.44	443	1096.90	7.203	1.2695	0.01139	3173.84	838	1312.21	2.117	0.9790	0.00241
1223.74	448	1095.81	6.951	1.2713	0.01099	3197.66	843	1324.33	2.197	0.9641	0.00248
1247.66	453	1093.81	6.704	1.2744	0.01061	3224.52	848	1335.40	2.242	0.9506	0.00250
1272.02	458	1091.80	6.444	1.2777	0.01021	3246.31	853	1346.37	2.284	0.9373	0.00252
1297.55	463	1091.26	6.191	1.2785	0.00980	3274.71	859	1359.20	2.328	0.9219	0.00253
1321.67	468	1091.58	5.962	1.2780	0.00943	3298.23	863	1367.77	2.358	0.9117	0.00254
1347.03	473	1091.38	5.743	1.2783	0.00908	3322.80	868	1378.21	2.393	0.8993	0.00254
1371.34	477	1091.33	5.566	1.2784	0.00879	3348.76	873	1388.65	2.427	0.8870	0.00255
1396.42	483	1090.53	5.305	1.2797	0.00837	3371.17	878	1398.72	2.454	0.8753	0.00254
1422.89	488	1090.08	5.104	1.2804	0.00805	3397.60	883	1408.58	2.484	0.8639	0.00254
1448.88	494	1090.23	4.870	1.2802	0.00767	3420.89	889	1421.13	2.532	0.8496	0.00256
1472.46	499	1089.58	4.698	1.2812	0.00740	3448.24	893	1428.94	2.549	0.8407	0.00255
1499.88	504	1088.81	4.524	1.2825	0.00712	3472.84	898	1438.93	2.579	0.8294	0.00255
1522.75	508	1087.92	4.393	1.2839	0.00691	3498.61	903	1448.51	2.604	0.8187	0.00254
1548.93	513	1087.36	4.242	1.2848	0.00667	3522.81	908	1457.85	2.624	0.8083	0.00253
1574.73	518	1086.00	4.096	1.2870	0.00644	3549.68	913	1467.98	2.666	0.7971	0.00255
1598.23	523	1084.67	3.957	1.2891	0.00622	3572.79	918	1478.51	2.713	0.7857	0.00257
1622.07	528	1083.56	3.815	1.2908	0.00600	3596.29	923	1487.64	2.724	0.7757	0.00254
1648.49	533	1082.73	3.680	1.2922	0.00578	3624.68	928	1497.71	2.751	0.7649	0.00255
1672.68	538	1081.57	3.558	1.2940	0.00558	3649.51	933	1505.66	2.741	0.7563	0.00249
1699.36	543	1080.46	3.442	1.2958	0.00540	3674.38	938	1515.63	2.781	0.7457	0.00251
1721.48	548	1079.76	3.329	1.2969	0.00522	3696.83	943	1524.02	2.789	0.7368	0.00248
1748.69	553	1078.89	3.231	1.2983	0.00506	3720.14	947	1531.36	2.810	0.7291	0.00248
1772.72	558	1077.99	3.127	1.2997	0.00490	3748.49	953	1541.60	2.821	0.7184	0.00246
1799.00	563	1077.41	3.030	1.3007	0.00474	3773.13	958	1550.72	2.849	0.7091	0.00246
1824.08	568	1076.90	2.930	1.3015	0.00458	3797.18	963	1558.69	2.855	0.7008	0.00243
1846.13	573	1076.79	2.840	1.3017	0.00443	3823.89	968	1566.57	2.860	0.6927	0.00241
1873.68	578	1076.85	2.752	1.3016	0.00429	3847.16	973	1574.54	2.869	0.6846	0.00238
1898.39	583	1076.56	2.676	1.3020	0.00416	3873.90	978	1582.46	2.880	0.6766	0.00236
1922.13	588	1076.51	2.599	1.3021	0.00404	3899.01	983	1590.91	2.898	0.6682	0.00235
1946.43	593	1076.97	2.524	1.3014	0.00392	3924.74	988	1598.90	2.919	0.6603	0.00235
1972.73	598	1077.19	2.458	1.3010	0.00381	3947.24	993	1606.60	2.929	0.6526	0.00233
1995.99	603	1077.25	2.392	1.3009	0.00370	3974.14	998	1614.19	2.940	0.6451	0.00230
2021.28	608	1077.49	2.327	1.3006	0.00359	3984.40	1000	1617.24	2.941	0.6422	0.00230

Table E.2: *a*, *b*, and $\chi = 0$, with maximum offsets increasing from 74.7 m to 3984.4 m, for all receivers, includes the longside only, (A+C). Best values (minimum standard error) are highlighted.

Max Offset (m)	# observations	*a*	Standard Error	*b*	Standard Error	Max Offset (m)	# observations	*a*	Standard Error	*b*	Standard Error
74.74	11	*1669.12*	34.30	*0.4852*	0.04044	2047.77	411	*1075.73*	2.80	*1.3031*	0.00425
93.23	18	*1656.88*	21.47	*0.4996*	0.02549	2073.48	417	*1076.66*	2.73	*1.3016*	0.00412
114.92	23	*1657.78*	18.51	*0.4984*	0.02197	2099.20	421	*1077.07*	2.67	*1.3010*	0.00403
136.23	28	*1661.64*	24.71	*0.4941*	0.02928	2122.91	426	*1077.88*	2.62	*1.2997*	0.00394
159.55	33	*1665.29*	22.33	*0.4897*	0.02642	2146.80	431	*1078.95*	2.56	*1.2981*	0.00384
185.80	38	*1665.45*	19.53	*0.4895*	0.02311	2171.82	436	*1078.68*	2.53	*1.2985*	0.00379
224.32	45	*1663.34*	17.56	*0.4920*	0.02080	2195.22	440	*1079.02*	2.47	*1.2980*	0.00370
247.11	50	*1677.33*	17.49	*0.4754*	0.02059	2223.37	447	*1081.29*	2.42	*1.2944*	0.00361
273.34	55	*1683.35*	17.58	*0.4685*	0.02064	2249.94	451	*1082.19*	2.39	*1.2931*	0.00356
299.43	61	*1678.60*	18.26	*0.4742*	0.02148	2272.62	456	*1083.84*	2.36	*1.2905*	0.00349
324.60	66	*1678.72*	18.45	*0.4742*	0.02170	2299.83	462	*1086.09*	2.33	*1.2870*	0.00344
346.83	70	*1672.04*	18.37	*0.4821*	0.02166	2323.30	466	*1087.17*	2.31	*1.2854*	0.00340
373.16	75	*1673.06*	18.57	*0.4810*	0.02189	2348.62	471	*1088.96*	2.28	*1.2826*	0.00335
396.72	80	*1660.90*	19.33	*0.4956*	0.02291	2373.84	476	*1090.84*	2.27	*1.2798*	0.00332
421.11	85	*1667.03*	19.50	*0.4884*	0.02304	2397.57	481	*1092.89*	2.26	*1.2766*	0.00330
447.16	90	*1656.71*	20.01	*0.5007*	0.02374	2423.96	486	*1094.93*	2.25	*1.2735*	0.00327
473.07	96	*1652.81*	20.83	*0.5055*	0.02476	2448.35	491	*1096.60*	2.24	*1.2710*	0.00324
497.01	100	*1646.48*	23.89	*0.5132*	0.02846	2472.64	496	*1098.34*	2.22	*1.2684*	0.00321
523.77	106	*1615.77*	26.62	*0.5504*	0.03215	2497.27	501	*1100.29*	2.22	*1.2654*	0.00319
549.68	111	*1600.55*	28.41	*0.5690*	0.03453	2524.87	506	*1102.14*	2.21	*1.2627*	0.00316
574.42	116	*1565.41*	31.08	*0.6123*	0.03838	2548.53	511	*1103.97*	2.19	*1.2599*	0.00313
598.16	120	*1536.58*	31.98	*0.6484*	0.04000	2571.80	516	*1105.71*	2.18	*1.2573*	0.00311
624.92	126	*1465.85*	32.61	*0.7129*	0.04178	2596.86	521	*1107.44*	2.17	*1.2547*	0.00308
648.93	131	*1441.98*	32.08	*0.7699*	0.04199	2621.38	526	*1109.01*	2.15	*1.2524*	0.00305
674.71	136	*1399.09*	31.27	*0.8269*	0.04183	2649.52	532	*1111.45*	2.15	*1.2487*	0.00303
695.53	141	*1360.12*	29.71	*0.8798*	0.04055	2674.60	536	*1112.73*	2.14	*1.2468*	0.00301
722.97	146	*1327.84*	28.23	*0.9244*	0.03920	2698.02	540	*1114.33*	2.14	*1.2445*	0.00300
747.80	152	*1293.56*	25.85	*0.9727*	0.03657	2723.23	546	*1116.53*	2.13	*1.2412*	0.00297
772.71	156	*1269.15*	25.01	*1.0076*	0.03587	2747.23	551	*1120.28*	1.78	*1.2359*	0.00246
799.36	161	*1244.28*	23.30	*1.0437*	0.03390	2773.23	556	*1131.62*	1.46	*1.2200*	0.00200
822.94	165	*1225.74*	22.36	*1.0710*	0.03288	2795.75	560	*1139.47*	1.58	*1.2090*	0.00214
847.58	171	*1195.41*	20.56	*1.1162*	0.03079	2823.37	565	*1151.74*	1.49	*1.1921*	0.00198
873.16	176	*1177.33*	19.37	*1.1436*	0.02931	2849.91	571	*1166.78*	1.49	*1.1716*	0.00195
898.70	181	*1167.06*	17.95	*1.1593*	0.02732	2872.44	575	*1176.24*	1.48	*1.1588*	0.00191
921.31	185	*1159.14*	17.38	*1.1715*	0.02656	2895.99	580	*1189.43*	1.65	*1.1412*	0.00211
947.13	191	*1139.34*	16.03	*1.2021*	0.02480	2922.93	586	*1203.85*	1.68	*1.1221*	0.00211
972.35	195	*1132.73*	15.22	*1.2124*	0.02364	2946.35	591	*1215.97*	1.77	*1.1062*	0.00220
997.99	202	*1132.68*	13.91	*1.2125*	0.02158	2973.59	596	*1227.63*	1.80	*1.0911*	0.00221
1023.52	206	*1126.05*	13.52	*1.2229*	0.02105	2995.88	601	*1239.83*	1.88	*1.0754*	0.00227
1047.73	210	*1119.83*	12.90	*1.2327*	0.02015	3023.06	606	*1252.96*	2.01	*1.0587*	0.00241
1074.36	216	*1114.06*	12.00	*1.2418*	0.01880	3047.19	611	*1264.67*	2.03	*1.0438*	0.00239
1098.09	221	*1109.63*	11.39	*1.2488*	0.01787	3072.06	616	*1277.53*	2.15	*1.0278*	0.00251
1124.22	226	*1104.01*	10.85	*1.2578*	0.01707	3097.79	621	*1289.93*	2.21	*1.0124*	0.00254
1149.32	231	*1098.30*	10.29	*1.2669*	0.01624	3123.28	626	*1300.92*	2.22	*0.9989*	0.00251
1174.60	236	*1093.65*	9.78	*1.2743*	0.01547	3147.80	631	*1313.43*	2.32	*0.9837*	0.00260
1196.44	241	*1091.66*	9.28	*1.2775*	0.01468	3173.84	636	*1325.32*	2.36	*0.9693*	0.00262
1223.74	246	*1090.39*	8.88	*1.2795*	0.01404	3197.66	641	*1336.96*	2.41	*0.9554*	0.00263
1247.66	251	*1088.03*	8.50	*1.2833*	0.01345	3224.52	646	*1349.01*	2.49	*0.9411*	0.00270
1272.02	256	*1085.76*	8.11	*1.2870*	0.01283	3246.31	651	*1359.47*	2.49	*0.9287*	0.00265
1297.55	261	*1085.42*	7.73	*1.2875*	0.01223	3274.71	657	*1372.56*	2.52	*0.9135*	0.00265
1321.67	266	*1086.14*	7.41	*1.2864*	0.01170	3298.23	661	*1381.30*	2.55	*0.9033*	0.00265
1347.03	271	*1086.20*	7.12	*1.2863*	0.01121	3322.80	666	*1392.80*	2.61	*0.8902*	0.00269
1371.34	275	*1086.36*	6.88	*1.2860*	0.01082	3348.76	671	*1403.42*	2.64	*0.8781*	0.00268
1396.42	281	*1085.73*	6.53	*1.2871*	0.01026	3371.17	676	*1414.40*	2.69	*0.8657*	0.00272
1422.89	286	*1085.46*	6.26	*1.2875*	0.00983	3397.60	681	*1425.44*	2.75	*0.8534*	0.00274
1448.88	292	*1085.93*	5.96	*1.2867*	0.00934	3420.89	687	*1436.58*	2.73	*0.8409*	0.00267
1472.46	297	*1085.42*	5.74	*1.2876*	0.00899	3448.24	691	*1444.45*	2.74	*0.8322*	0.00266
1499.88	302	*1084.74*	5.52	*1.2886*	0.00864	3472.84	696	*1454.49*	2.77	*0.8211*	0.00265
1522.75	306	*1083.89*	5.36	*1.2900*	0.00838	3498.61	701	*1465.13*	2.82	*0.8096*	0.00267
1548.93	311	*1083.45*	5.18	*1.2907*	0.00809	3522.81	706	*1475.38*	2.86	*0.7985*	0.00269
1574.73	316	*1082.11*	5.00	*1.2929*	0.00781	3549.68	711	*1484.98*	2.87	*0.7882*	0.00266
1598.23	321	*1080.79*	4.84	*1.2950*	0.00754	3572.79	716	*1496.68*	2.94	*0.7758*	0.00272
1622.07	326	*1079.72*	4.66	*1.2967*	0.00726	3596.29	721	*1506.06*	2.94	*0.7659*	0.00268
1648.49	331	*1078.96*	4.49	*1.2979*	0.00699	3624.68	726	*1514.26*	2.92	*0.7571*	0.00261
1672.68	336	*1077.84*	4.35	*1.2997*	0.00676	3649.51	731	*1523.12*	2.92	*0.7479*	0.00258
1699.36	341	*1076.75*	4.21	*1.3014*	0.00654	3674.38	736	*1533.05*	2.96	*0.7376*	0.00260
1721.48	346	*1076.14*	4.07	*1.3024*	0.00632	3696.83	741	*1542.49*	2.99	*0.7279*	0.00259
1748.69	351	*1075.32*	3.96	*1.3037*	0.00613	3720.14	745	*1549.94*	3.00	*0.7203*	0.00259
1772.72	356	*1074.47*	3.83	*1.3050*	0.00593	3748.49	751	*1560.21*	3.01	*0.7099*	0.00256
1799.00	361	*1073.97*	3.71	*1.3058*	0.00574	3773.13	756	*1569.07*	3.03	*0.7010*	0.00256
1824.08	366	*1073.54*	3.59	*1.3065*	0.00554	3797.18	761	*1577.30*	3.03	*0.6927*	0.00252
1846.13	371	*1073.56*	3.48	*1.3065*	0.00536	3823.89	766	*1584.51*	3.01	*0.6854*	0.00246
1873.68	376	*1073.77*	3.38	*1.3062*	0.00519	3847.16	771	*1592.52*	3.02	*0.6774*	0.00243
1898.39	381	*1073.58*	3.29	*1.3065*	0.00504	3873.90	776	*1601.40*	3.04	*0.6687*	0.00243
1922.13	386	*1073.63*	3.19	*1.3064*	0.00489	3899.01	781	*1609.44*	3.06	*0.6609*	0.00242
1946.43	391	*1074.28*	3.10	*1.3053*	0.00474	3924.74	786	*1617.03*	3.06	*0.6534*	0.00239
1972.73	396	*1074.65*	3.03	*1.3048*	0.00462	3947.24	791	*1625.59*	3.08	*0.6452*	0.00239
1995.99	401	*1074.81*	2.95	*1.3045*	0.00449	3974.14	796	*1634.08*	3.10	*0.6371*	0.00239
2021.28	406	*1075.18*	2.87	*1.3039*	0.00436	3984.40	798	*1636.32*	3.09	*0.6349*	0.00235

Table E.3: *a*, *b*, and $\chi = 0$, with maximum offsets increasing from 2850.0 m to 3984.4 m, for all receivers, for the longside, longoffsets only, (D+C). Best values (minimum standard error) are highlighted.

Max Offset (m)	# observations	a	Standard Error	b	Standard Error	Max Offset (m)	# observations	a	Standard Error	b	Standard Error
2849.91	11	1790.44	89.51	0.5086	0.09086	3448.24	131	1536.78	1.69	0.7788	0.00159
2872.44	15	1777.71	101.54	0.5222	0.10307	3472.84	136	1550.00	1.78	0.7659	0.00167
2895.99	20	1687.96	94.53	0.6142	0.09660	3498.61	141	1559.14	1.81	0.7570	0.00169
2922.93	26	1553.33	89.97	0.7536	0.09336	3522.81	146	1566.85	1.65	0.7496	0.00152
2946.35	31	1513.93	70.44	0.7948	0.07346	3549.68	151	1577.74	1.74	0.7391	0.00159
2973.59	36	1459.79	62.29	0.8518	0.06550	3572.79	156	1594.29	2.09	0.7233	0.00194
2995.88	41	1406.24	52.53	0.9087	0.05576	3596.29	161	1599.48	1.84	0.7183	0.00167
3023.06	46	1313.09	1.57	1.0085	0.00159	3624.68	166	1606.46	1.75	0.7117	0.00155
3047.19	51	1327.52	1.49	0.9930	0.00151	3649.51	171	1614.91	1.67	0.7037	0.00145
3072.06	56	1343.78	1.51	0.9756	0.00152	3674.38	176	1634.06	2.37	0.6857	0.00217
3097.79	61	1359.43	1.42	0.9589	0.00143	3696.83	181	1638.14	2.09	0.6820	0.00188
3123.28	66	1371.35	1.16	0.9463	0.00113	3720.14	185	1641.02	1.83	0.6792	0.00158
3147.80	71	1388.00	1.45	0.9290	0.00145	3748.49	191	1651.06	1.76	0.6699	0.00149
3173.84	76	1402.36	1.43	0.9140	0.00142	3773.13	196	1659.66	1.77	0.6619	0.00147
3197.66	81	1416.23	1.44	0.8997	0.00143	3797.18	201	1669.88	1.88	0.6527	0.00158
3224.52	86	1428.04	1.21	0.8875	0.00117	3823.89	206	1677.67	1.83	0.6455	0.00151
3246.31	91	1441.49	1.49	0.8738	0.00147	3847.16	211	1687.06	1.98	0.6370	0.00165
3274.71	97	1452.49	1.26	0.8626	0.00121	3873.90	216	1697.45	2.14	0.6276	0.00182
3298.23	101	1467.25	1.32	0.8476	0.00126	3899.01	221	1702.45	1.86	0.6231	0.00149
3322.80	106	1478.55	1.34	0.8363	0.00128	3924.74	226	1709.20	1.82	0.6170	0.00144
3348.76	111	1049.65	94.57	1.0755	0.04128	3947.24	231	1717.60	1.91	0.6094	0.00150
3371.17	116	1501.08	1.46	0.8138	0.00138	3974.14	236	1731.45	2.34	0.5972	0.00197
3397.60	121	1513.67	1.54	0.8014	0.00146	3984.40	238	1728.73	1.95	0.5996	0.00153
3420.89	127	1520.91	1.31	0.7944	0.00119						

Table E.4: *a*, *b*, and $\chi = 0$, with maximum offsets increasing from 73.2 m to 1014.1 m, for all receivers, for the shortside only, (B). Best values (minimum standard error) are highlighted.

Max Offset (m)	# observations	a	Standard Error	b	Standard Error	Max Offset (m)	# observations	a	Standard Error	b	Standard Error
73.17	8	1658.04	50.06	0.4988	0.0593	573.81	114	1479.34	29.54	0.7216	0.0380
99.57	15	1648.20	28.86	0.5102	0.0344	599.45	119	1453.93	30.04	0.7546	0.0391
119.62	21	1663.77	21.90	0.4917	0.0259	624.84	124	1420.28	29.17	0.7990	0.0386
142.49	26	1657.95	21.68	0.4986	0.0257	646.13	129	1387.88	28.40	0.8425	0.0382
174.10	32	1639.47	23.28	0.5208	0.0279	671.18	133	1364.94	27.87	0.8737	0.0380
195.77	37	1647.54	23.06	0.5114	0.0275	698.48	139	1330.05	25.75	0.9219	0.0357
224.50	43	1668.16	22.51	0.4869	0.0266	722.70	144	1299.97	24.47	0.9641	0.0345
246.71	48	1668.35	20.45	0.4867	0.0242	748.24	149	1269.59	23.07	1.0076	0.0331
269.42	52	1665.95	19.24	0.4895	0.0228	771.35	154	1243.91	21.83	1.0449	0.0318
297.14	58	1657.90	17.81	0.4991	0.0211	798.75	159	1219.84	20.45	1.0803	0.0302
324.69	64	1654.99	17.59	0.5027	0.0209	823.75	164	1194.71	19.26	1.1179	0.0289
347.76	68	1646.31	17.44	0.5130	0.0208	847.08	169	1177.73	18.27	1.1437	0.0277
373.06	73	1639.49	19.12	0.5214	0.0229	872.46	174	1167.54	17.08	1.1592	0.0260
399.63	79	1627.97	20.52	0.5354	0.0247	898.67	179	1155.05	15.96	1.1785	0.0245
419.78	83	1619.08	21.86	0.5462	0.0264	924.31	184	1141.38	15.04	1.1997	0.0233
444.64	88	1603.83	24.68	0.5649	0.0300	949.15	189	1129.69	14.15	1.2179	0.0220
470.94	94	1577.65	26.90	0.5972	0.0331	972.73	194	1117.82	13.32	1.2366	0.0209
497.40	99	1560.18	28.18	0.6189	0.0349	997.09	199	1109.12	12.66	1.2504	0.0200
519.69	104	1545.04	28.38	0.6379	0.0354	1014.08	202	1102.85	12.28	1.2604	0.0194
544.98	108	1528.55	28.40	0.6587	0.0357						

Table E.5: a, b, and $\chi = 0$, with maximum offsets increasing from 74.7 m to 1014.4 m, for all receivers, for the longside, shortoffsets only (B'). This is the same as Table E.2 up to the offset of 998.0 m, and is included here for comparison with results for the shortside only (B), Table E.4. Best values (minimum standard error) are highlighted.

Max Offset (m)	# observations	*a*	Standard Error	*b*	Standard Error	Max Offset (m)	# observations	*a*	Standard Error	*b*	Standard Error
74.74	11	*1669.12*	34.30	*0.4852*	0.04044	574.42	116	*1565.41*	31.08	*0.6123*	0.03838
93.23	18	*1656.88*	21.47	*0.4996*	0.02549	598.16	120	*1536.58*	31.98	*0.6484*	0.04000
114.92	23	*1657.78*	18.51	*0.4984*	0.02197	624.92	126	*1485.85*	32.61	*0.7129*	0.04178
136.23	28	*1661.64*	24.71	*0.4941*	0.02928	648.93	131	*1441.98*	32.08	*0.7699*	0.04199
159.55	33	*1665.29*	22.33	*0.4897*	0.02642	674.71	136	*1399.09*	31.27	*0.8269*	0.04183
185.80	38	*1665.45*	19.53	*0.4895*	0.02311	695.53	141	*1360.12*	29.71	*0.8798*	0.04055
224.32	45	*1663.34*	17.56	*0.4920*	0.02080	722.97	146	*1327.84*	28.23	*0.9244*	0.03920
247.11	50	*1677.33*	17.49	*0.4754*	0.02059	747.80	152	*1293.56*	25.85	*0.9727*	0.03657
273.34	55	*1683.35*	17.58	*0.4685*	0.02064	772.71	156	*1269.15*	25.01	*1.0076*	0.03587
299.43	61	*1678.60*	18.26	*0.4742*	0.02148	799.36	161	*1244.28*	23.30	*1.0437*	0.03390
324.60	66	*1678.72*	18.45	*0.4742*	0.02170	822.94	165	*1225.74*	22.36	*1.0710*	0.03288
346.83	70	*1672.04*	18.37	*0.4821*	0.02166	847.58	171	*1195.41*	20.56	*1.1162*	0.03079
373.16	75	*1673.06*	18.57	*0.4810*	0.02189	873.16	176	*1177.33*	19.37	*1.1436*	0.02931
396.72	80	*1660.90*	19.33	*0.4956*	0.02291	898.70	181	*1167.06*	17.95	*1.1593*	0.02732
421.11	85	*1667.03*	19.50	*0.4884*	0.02304	921.31	185	*1159.14*	17.38	*1.1715*	0.02656
447.16	90	*1656.71*	20.01	*0.5007*	0.02374	947.13	191	*1139.34*	16.03	*1.2021*	0.02480
473.07	96	*1652.81*	20.83	*0.5055*	0.02476	972.35	195	*1132.73*	15.22	*1.2124*	0.02364
497.01	100	*1646.48*	23.89	*0.5132*	0.02846	997.99	202	*1132.68*	13.91	*1.2125*	0.02158
523.77	106	*1615.77*	26.62	*0.5504*	0.03215	1014.40	203	*1127.83*	13.92	*1.2201*	0.02165
549.68	111	*1600.55*	28.41	*0.5690*	0.03453						

Table E.6: *a*, *b*, and χ, with maximum offsets increasing from 47.9 m to 3984.4 m, for all receivers, includes longside and shortside, (A+B+C). Best values (minimum standard error) are highlighted. Ambiguous values are obtained when rays are close to vertical resulting in large standard errors.

Max Offset (m)	# observations	a	Standard Error	b	Standard Error	χ	Standard Error	Max Offset (m)	# observations	a	Standard Error	b	Standard Error	χ	Standard Error
47.92	19	2000.11	70904.71	0.9503	90.02314	0.0002	378.202456	2047.77	613	1283.48	13.05	0.9816	0.01886	0.0427	0.002341
99.57	33	2000.34	35984.99	0.9507	45.88702	0.0002	130.112478	2073.48	619	1272.68	12.54	0.9972	0.01824	0.0411	0.002312
119.62	44	2000.60	26729.16	0.9512	34.22440	0.0002	59.835778	2099.20	623	1265.29	12.22	1.0079	0.01787	0.0400	0.002295
142.49	54	1654.92	16.52	0.5019	0.01960	0.0542	0.043993	2122.91	628	1257.97	11.81	1.0186	0.01735	0.0388	0.002263
174.10	65	1649.98	15.96	0.5077	0.01899	0.0611	0.030271	2146.80	633	1253.04	11.40	1.0258	0.01680	0.0381	0.002222
195.77	75	1655.24	14.86	0.5014	0.01765	0.0584	0.021008	2171.82	638	1239.81	11.18	1.0453	0.01662	0.0359	0.002241
224.50	88	1663.64	14.54	0.4917	0.01721	0.0269	0.013325	2195.22	642	1232.45	10.84	1.0562	0.01619	0.0346	0.002211
247.11	98	1672.45	14.11	0.4814	0.01664	0.0074	0.009835	2223.37	649	1233.20	10.33	1.0551	0.01543	0.0348	0.002135
273.34	107	1674.41	13.28	0.4790	0.01565	0.0131	0.007920	2249.94	653	1231.66	10.08	1.0574	0.01508	0.0345	0.002105
299.43	119	1668.50	12.36	0.4859	0.01460	0.0211	0.006144	2272.62	658	1232.47	9.74	1.0562	0.01456	0.0347	0.002051
324.69	130	1669.43	11.63	0.4848	0.01374	0.0264	0.004963	2299.83	664	1235.55	9.38	1.0516	0.01401	0.0353	0.001992
347.76	138	1663.08	11.21	0.4923	0.01328	0.0267	0.004278	2323.30	668	1235.13	9.15	1.0522	0.01367	0.0353	0.001959
373.16	148	1664.17	10.85	0.4909	0.01284	0.0314	0.003664	2348.62	673	1237.04	8.86	1.0493	0.01323	0.0356	0.001912
399.63	159	1659.58	10.45	0.4963	0.01239	0.0347	0.003113	2373.84	678	1239.60	8.60	1.0455	0.01283	0.0361	0.001869
421.11	168	1662.39	10.56	0.4929	0.01251	0.0348	0.002840	2397.57	683	1243.16	8.36	1.0402	0.01245	0.0368	0.001826
447.16	178	1659.40	10.63	0.4964	0.01261	0.0377	0.002590	2423.96	688	1246.48	8.13	1.0353	0.01208	0.0375	0.001785
473.07	190	1659.63	10.77	0.4961	0.01278	0.0396	0.002343	2448.35	693	1247.45	7.90	1.0339	0.01173	0.0377	0.001749
497.40	199	1662.55	10.70	0.4926	0.01268	0.0430	0.002176	2472.64	698	1248.87	7.67	1.0318	0.01139	0.0380	0.001713
523.77	210	1659.68	10.33	0.4959	0.01225	0.0439	0.001911	2497.27	703	1251.45	7.45	1.0280	0.01105	0.0385	0.001675
549.68	219	1660.25	10.12	0.4953	0.01201	0.0441	0.001741	2524.87	708	1253.42	7.25	1.0250	0.01075	0.0389	0.001642
574.42	230	1657.13	10.15	0.4989	0.01206	0.0474	0.001623	2548.53	713	1254.98	7.02	1.0228	0.01041	0.0392	0.001603
599.45	239	1659.65	9.93	0.4958	0.01178	0.0487	0.001495	2571.80	718	1256.19	6.82	1.0210	0.01010	0.0395	0.001571
624.92	250	1658.37	9.60	0.4973	0.01140	0.0491	0.001342	2596.86	723	1257.42	6.64	1.0191	0.00983	0.0397	0.001541
648.93	260	1657.74	9.33	0.4980	0.01108	0.0497	0.001228	2621.38	728	1257.59	6.44	1.0189	0.00954	0.0398	0.001510
674.71	269	1659.15	9.08	0.4963	0.01077	0.0502	0.001134	2649.52	734	1260.98	6.23	1.0139	0.00921	0.0405	0.001471
698.48	280	1656.91	8.78	0.4990	0.01043	0.0504	0.001036	2674.60	738	1261.32	6.08	1.0134	0.00899	0.0406	0.001447
722.97	290	1657.65	8.62	0.4981	0.01023	0.0511	0.000969	2698.02	742	1263.31	5.95	1.0105	0.00879	0.0410	0.001422
748.24	301	1654.65	8.54	0.5016	0.01016	0.0518	0.000919	2723.23	748	1265.03	5.74	1.0079	0.00848	0.0413	0.001387
772.71	310	1655.71	8.58	0.5003	0.01019	0.0530	0.000889	2747.23	753	1266.67	5.58	1.0055	0.00823	0.0417	0.001358
799.36	320	1652.54	8.62	0.5040	0.01026	0.0538	0.000862	2773.23	758	1268.30	5.42	1.0031	0.00799	0.0420	0.001329
823.75	329	1652.54	8.96	0.5039	0.01066	0.0553	0.000871	2795.75	762	1268.82	5.30	1.0024	0.00782	0.0421	0.001309
847.58	340	1652.33	9.12	0.5040	0.01086	0.0569	0.000857	2823.37	767	1268.49	5.13	1.0029	0.00758	0.0421	0.001281
873.16	350	1652.52	9.05	0.5038	0.01077	0.0577	0.000827	2849.91	773	1268.21	4.93	1.0033	0.00729	0.0420	0.001246
898.70	360	1647.50	9.07	0.5097	0.01082	0.0580	0.000811	2872.44	777	1268.22	4.82	1.0032	0.00712	0.0420	0.001227
924.31	369	1650.00	9.39	0.5066	0.01119	0.0592	0.000821	2895.99	782	1268.88	4.68	1.0023	0.00692	0.0422	0.001203
949.15	380	1645.42	9.75	0.5120	0.01164	0.0604	0.000837	2922.93	788	1269.19	4.53	1.0018	0.00670	0.0423	0.001178
972.73	389	1641.78	9.94	0.5162	0.01189	0.0612	0.000844	2946.35	793	1270.92	4.41	0.9993	0.00652	0.0426	0.001156
997.99	401	1641.48	10.20	0.5166	0.01220	0.0615	0.000850	2973.59	798	1272.00	4.31	0.9977	0.00637	0.0429	0.001138
1023.52	408	1645.83	10.25	0.5113	0.01224	0.0622	0.000834	2995.88	803	1272.66	4.19	0.9967	0.00620	0.0430	0.001117
1047.73	412	1644.92	10.21	0.5124	0.01219	0.0624	0.000827	3023.06	808	1273.83	4.09	0.9950	0.00604	0.0433	0.001098
1074.36	418	1644.74	10.10	0.5126	0.01207	0.0627	0.000811	3047.19	813	1274.36	3.98	0.9942	0.00588	0.0434	0.001079
1098.09	423	1645.29	10.05	0.5119	0.01200	0.0631	0.000801	3072.06	818	1276.09	3.89	0.9917	0.00575	0.0438	0.001063
1124.22	428	1645.66	10.15	0.5114	0.01212	0.0637	0.000804	3097.79	823	1277.51	3.79	0.9896	0.00560	0.0441	0.001045
1149.32	433	1644.04	10.30	0.5133	0.01231	0.0643	0.000814	3123.28	828	1269.78	0.77	1.0011	0.00106	0.0420	0.000285
1174.60	438	1642.56	10.45	0.5149	0.01249	0.0648	0.000823	3147.80	833	1280.27	1.00	0.9856	0.00142	0.0448	0.000334
1196.44	443	1640.81	10.43	0.5170	0.01248	0.0651	0.000820	3173.84	838	1288.56	0.99	0.9733	0.00139	0.0470	0.000331
1223.74	448	1641.49	10.44	0.5161	0.01249	0.0656	0.000817	3197.66	843	1297.17	0.98	0.9607	0.00137	0.0494	0.000330
1247.66	453	1641.17	10.59	0.5164	0.01266	0.0662	0.000827	3224.52	848	1304.49	0.74	0.9500	0.00099	0.0513	0.000280
1272.02	458	1638.87	10.73	0.5191	0.01285	0.0667	0.000840	3246.31	853	1312.26	0.74	0.9386	0.00099	0.0535	0.000282
1297.55	463	1637.06	10.72	0.5212	0.01284	0.0670	0.000840	3274.71	859	1319.62	0.74	0.9280	0.00099	0.0554	0.000285
1321.67	468	1636.69	10.66	0.5216	0.01277	0.0672	0.000835	3298.23	863	1329.36	0.76	0.9139	0.00100	0.0581	0.000291
1347.03	473	1635.93	10.68	0.5225	0.01280	0.0676	0.000838	3322.80	868	1336.06	0.76	0.9042	0.00100	0.0599	0.000295
1371.34	477	1633.93	10.67	0.5248	0.01281	0.0678	0.000841	3348.76	873	1344.52	0.78	0.8921	0.00102	0.0622	0.000303
1396.42	483	1630.53	10.84	0.5288	0.01303	0.0683	0.000861	3371.17	878	1350.16	0.68	0.8840	0.00085	0.0638	0.000288
1422.89	488	1627.44	10.96	0.5325	0.01320	0.0686	0.000878	3397.60	883	1358.17	0.70	0.8726	0.00087	0.0661	0.000297
1448.88	494	1622.23	11.09	0.5387	0.01339	0.0689	0.000902	3420.89	889	1363.78	0.71	0.8646	0.00088	0.0677	0.000303
1472.46	499	1618.51	11.32	0.5431	0.01369	0.0692	0.000931	3448.24	893	1372.95	0.73	0.8516	0.00090	0.0703	0.000315
1499.88	504	1612.97	11.60	0.5497	0.01405	0.0695	0.000968	3472.84	898	1382.46	0.87	0.8382	0.00111	0.0729	0.000349
1522.75	508	1609.42	11.83	0.5539	0.01436	0.0697	0.000997	3498.61	903	1387.62	0.77	0.8309	0.00093	0.0743	0.000336
1548.93	513	1603.99	12.15	0.5604	0.01479	0.0700	0.001041	3522.81	908	1393.35	0.78	0.8229	0.00095	0.0760	0.000343
1574.73	518	1595.32	12.71	0.5708	0.01554	0.0702	0.001116	3549.68	913	1400.72	0.80	0.8125	0.00097	0.0781	0.000355
1598.23	523	1585.25	13.28	0.5830	0.01630	0.0702	0.001197	3572.79	918	1411.21	0.97	0.7979	0.00121	0.0811	0.000398
1622.07	528	1573.20	13.73	0.5977	0.01696	0.0700	0.001277	3596.29	923	1413.46	0.85	0.7949	0.00101	0.0816	0.000379
1648.49	533	1560.64	14.11	0.6132	0.01752	0.0696	0.001355	3624.68	928	1420.67	0.87	0.7848	0.00103	0.0837	0.000391
1672.68	538	1546.21	14.59	0.6310	0.01825	0.0691	0.001453	3649.51	933	1425.82	0.81	0.7777	0.00091	0.0853	0.000389
1699.36	543	1530.09	15.04	0.6511	0.01896	0.0684	0.001559	3674.38	938	1437.95	1.40	0.7609	0.00179	0.0888	0.000510
1721.48	548	1514.02	15.32	0.6713	0.01947	0.0675	0.001651	3696.83	943	1439.87	0.85	0.7583	0.00095	0.0893	0.000416
1748.69	553	1496.72	15.67	0.6932	0.02009	0.0665	0.001760	3720.14	947	1443.43	0.87	0.7534	0.00097	0.0904	0.000427
1772.72	558	1475.05	15.90	0.7210	0.02061	0.0648	0.001876	3748.49	953	1449.79	0.84	0.7447	0.00089	0.0923	0.000430
1799.00	563	1454.63	16.00	0.7475	0.02096	0.0631	0.001976	3773.13	958	1457.34	0.93	0.7343	0.00101	0.0946	0.000458
1824.08	568	1431.49	15.97	0.7779	0.02118	0.0610	0.002074	3797.18	963	1463.20	0.93	0.7263	0.00101	0.0965	0.000464
1846.13	573	1412.03	15.81	0.8037	0.02119	0.0590	0.002143	3823.89	968	1467.53	0.90	0.7204	0.00093	0.0977	0.000469
1873.68	578	1393.26	15.57	0.8289	0.02107	0.0570	0.002198	3847.16	973	1473.59	0.92	0.7121	0.00095	0.0996	0.000486
1898.39	583	1372.60	15.37	0.8569	0.02106	0.0546	0.002267	3873.90	978	1481.11	1.00	0.7019	0.00106	0.1020	0.000506
1922.13	588	1353.71	15.07	0.8828	0.02086	0.0523	0.002313	3899.01	983	1484.49	0.95	0.6973	0.00096	0.1030	0.000503
1946.43	593	1339.42	14.65	0.9026	0.02045	0.0505	0.002322	3924.74	988	1488.55	0.93	0.6918	0.00091	0.1043	0.000512
1972.73	598	1324.61	14.29	0.9232	0.02013	0.0486	0.002340	3947.24	993	1495.82	1.01	0.6819	0.00101	0.1067	0.000542
1995.99	603	1308.55	13.90	0.9459	0.01977	0.0464	0.002355	3974.14	998	1503.14	1.09	0.6720	0.00113	0.1090	0.000565
2021.28	608	1294.73	13.47	0.9655	0.01933	0.0444	0.002353	3984.40	1000	1502.01	0.98	0.6735	0.00094	0.1087	0.000552

Table E.7: *a*, *b*, and χ, with maximum offsets increasing from 69.7 m to 3984.4 m, for all receivers, for the longside only, (A+C). Best values (minimum standard error) are highlighted. Ambiguous values are obtained when rays are close to vertical resulting in large standard errors.

Max Offset (m)	# observations	*a*	Standard Error	*b*	Standard Error	χ	Standard Error	Max Offset (m)	# observations	*a*	Standard Error	*b*	Standard Error	χ	Standard Error
69.67	9	2000.09	139925.2081	0.9502	178.0073	0.0002	622.9144	2021.28	406	1278.75	16.4267	0.9875	0.02382	0.0432	0.003007
73.25	10	2000.11	103505.2859	0.9503	131.8120	0.0002	485.3994	2047.77	411	1268.88	15.8284	1.0017	0.02310	0.0416	0.002970
74.74	11	2000.11	87487.3000	0.9503	111.17851	0.0002	472.093590	2073.48	417	1260.06	15.1239	1.0146	0.02220	0.0403	0.002911
93.23	18	2000.55	51761.2955	0.9511	65.99247	0.0002	189.622034	2099.20	421	1253.60	14.6884	1.0240	0.02166	0.0392	0.002876
114.92	23	2000.29	39486.3098	0.9506	50.53036	0.0002	89.395875	2122.91	426	1247.76	14.1385	1.0326	0.02093	0.0383	0.002821
136.23	28	1651.81	22.9928	0.5051	0.02731	0.1660	0.089408	2146.80	431	1244.40	13.6009	1.0375	0.02019	0.0378	0.002756
159.55	33	1664.78	22.8133	0.4902	0.02697	0.0079	0.037432	2171.82	436	1231.41	13.3290	1.0567	0.01996	0.0356	0.002778
185.80	38	1665.18	19.8259	0.4898	0.02345	0.0057	0.023885	2195.22	440	1224.55	12.8643	1.0670	0.01936	0.0343	0.002729
224.32	45	1663.12	17.8894	0.4923	0.02117	0.0015	0.014741	2223.37	447	1227.85	12.2328	1.0620	0.01838	0.0350	0.002624
247.11	50	2004.84	24997.2688	0.9612	32.12677	0.0002	11.997892	2249.94	451	1227.30	11.9260	1.0628	0.01793	0.0349	0.002581
273.34	55	1682.10	17.4960	0.4697	0.02054	0.0130	0.010229	2272.62	456	1229.54	11.4945	1.0595	0.01727	0.0354	0.002507
299.43	61	1677.64	16.6957	0.4748	0.01964	0.0280	0.008344	2299.83	462	1234.41	11.0614	1.0522	0.01658	0.0363	0.002429
324.60	66	1679.46	15.5544	0.4726	0.01829	0.0331	0.006792	2323.30	466	1234.72	10.7744	1.0517	0.01615	0.0364	0.002384
346.83	70	1674.73	14.8605	0.4782	0.01751	0.0330	0.005807	2348.62	471	1237.73	10.4166	1.0472	0.01559	0.0370	0.002321
373.16	75	1678.88	13.9731	0.4733	0.01643	0.0337	0.004763	2373.84	476	1241.37	10.1069	1.0418	0.01510	0.0378	0.002265
396.72	80	1671.75	13.5079	0.4817	0.01594	0.0346	0.004060	2397.57	481	1245.98	9.8168	1.0349	0.01463	0.0387	0.002211
421.11	85	1681.38	13.5908	0.4704	0.01597	0.0321	0.003606	2423.96	486	1250.22	9.5344	1.0286	0.01418	0.0395	0.002158
447.16	90	1677.47	13.0519	0.4750	0.01536	0.0322	0.003103	2448.35	491	1251.75	9.2518	1.0264	0.01376	0.0399	0.002113
473.07	96	1682.65	12.5900	0.4689	0.01479	0.0324	0.002645	2472.64	496	1253.70	8.9741	1.0235	0.01334	0.0403	0.002066
497.01	100	1687.87	13.3294	0.4626	0.01562	0.0372	0.002656	2497.27	501	1256.86	8.7085	1.0188	0.01292	0.0409	0.002018
523.77	106	1680.75	13.5361	0.4709	0.01591	0.0406	0.002442	2524.87	506	1259.28	8.4662	1.0152	0.01255	0.0414	0.001977
549.68	111	1686.14	13.3716	0.4645	0.01568	0.0425	0.002238	2548.53	511	1261.16	8.1839	1.0125	0.01213	0.0418	0.001927
574.42	116	1685.51	13.7029	0.4651	0.01607	0.0463	0.002150	2571.80	516	1262.62	7.9377	1.0103	0.01176	0.0421	0.001886
598.16	120	1684.52	13.4008	0.4663	0.01573	0.0478	0.001999	2596.86	521	1264.07	7.7145	1.0082	0.01143	0.0425	0.001849
624.92	126	1685.58	12.9885	0.4650	0.01524	0.0495	0.001786	2621.38	526	1264.31	7.4735	1.0078	0.01107	0.0425	0.001810
648.93	131	1684.55	12.5514	0.4661	0.01473	0.0503	0.001625	2649.52	532	1268.05	7.2160	1.0023	0.01068	0.0433	0.001762
674.71	136	1686.16	12.2482	0.4642	0.01436	0.0514	0.001500	2674.60	536	1268.40	7.0326	1.0018	0.01041	0.0434	0.001731
695.53	141	1684.52	11.8676	0.4661	0.01393	0.0518	0.001379	2698.02	540	1270.57	6.8674	0.9986	0.01016	0.0439	0.001701
722.97	146	1686.66	11.5861	0.4635	0.01358	0.0524	0.001281	2723.23	546	1272.36	6.6187	0.9960	0.00979	0.0443	0.001657
747.80	152	1684.10	11.2298	0.4665	0.01318	0.0529	0.001182	2747.23	551	1274.07	6.4189	0.9935	0.00949	0.0446	0.001620
772.71	156	1686.85	11.2520	0.4632	0.01319	0.0540	0.001141	2773.23	556	1275.74	6.2224	0.9910	0.00919	0.0450	0.001584
799.36	161	1684.63	11.1155	0.4658	0.01304	0.0547	0.001084	2795.75	560	1276.22	6.0773	0.9903	0.00898	0.0451	0.001560
822.94	165	1687.93	11.3327	0.4619	0.01328	0.0560	0.001074	2823.37	565	1275.73	5.8740	0.9910	0.00869	0.0450	0.001525
847.58	171	1684.44	11.9221	0.4658	0.01399	0.0578	0.001087	2849.91	571	1275.25	5.6299	0.9917	0.00834	0.0449	0.001482
873.16	176	1685.82	12.1741	0.4641	0.01428	0.0592	0.001077	2872.44	575	1275.15	5.4943	0.9919	0.00815	0.0449	0.001459
898.70	181	1679.42	12.1719	0.4716	0.01432	0.0591	0.001050	2895.99	580	1275.73	5.3284	0.9910	0.00790	0.0450	0.001430
921.31	185	1686.21	12.5276	0.4636	0.01469	0.0602	0.001056	2922.93	586	1275.90	5.1505	0.9907	0.00765	0.0451	0.001400
947.13	191	1679.45	13.5566	0.4714	0.01594	0.0618	0.001118	2946.35	591	1277.63	5.0075	0.9882	0.00743	0.0455	0.001372
972.35	195	1676.27	13.4691	0.4751	0.01586	0.0622	0.001097	2973.59	596	1278.67	4.8840	0.9867	0.00725	0.0457	0.001351
997.99	202	1674.08	13.4288	0.4777	0.01583	0.0617	0.001067	2995.88	601	1279.23	4.7472	0.9859	0.00705	0.0459	0.001326
1023.52	206	1680.39	13.7764	0.4702	0.01620	0.0627	0.001070	3023.06	606	1280.34	4.6224	0.9842	0.00687	0.0461	0.001304
1047.73	210	1677.38	13.9074	0.4737	0.01637	0.0634	0.001073	3047.19	611	1280.76	4.4959	0.9836	0.00668	0.0462	0.001281
1074.36	216	1675.78	13.8001	0.4755	0.01626	0.0641	0.001048	3072.06	616	1282.47	4.3919	0.9811	0.00653	0.0467	0.001262
1098.09	221	1675.92	13.7892	0.4752	0.01624	0.0649	0.001036	3097.79	621	1283.83	4.2740	0.9791	0.00635	0.0470	0.001239
1124.22	226	1676.13	14.1482	0.4749	0.01667	0.0659	0.001053	3123.28	626	1269.94	1.1001	1.0000	0.00155	0.0429	0.000396
1149.32	231	1673.02	14.5836	0.4784	0.01720	0.0668	0.001083	3147.80	631	1279.45	1.0759	0.9857	0.00150	0.0456	0.000390
1174.60	236	1670.43	14.9054	0.4814	0.01760	0.0676	0.001104	3173.84	636	1287.66	1.0590	0.9735	0.00147	0.0479	0.000385
1196.44	241	1667.23	14.8349	0.4851	0.01754	0.0680	0.001099	3197.66	641	1296.18	1.0448	0.9608	0.00144	0.0504	0.000382
1223.74	246	1668.59	14.7636	0.4834	0.01745	0.0686	0.001087	3224.52	646	1303.13	0.8036	0.9505	0.00104	0.0523	0.000329
1247.66	251	1668.64	14.9667	0.4833	0.01769	0.0694	0.001099	3246.31	651	1310.78	0.8029	0.9392	0.00103	0.0545	0.000331
1272.02	256	1665.41	15.1616	0.4870	0.01795	0.0700	0.001118	3274.71	657	1318.05	0.8057	0.9286	0.00103	0.0566	0.000333
1297.55	261	1662.81	15.0249	0.4900	0.01780	0.0703	0.001111	3298.23	661	1327.60	0.8152	0.9146	0.00104	0.0593	0.000340
1321.67	266	1662.62	14.8035	0.4902	0.01754	0.0706	0.001095	3322.80	666	1334.22	0.8213	0.9049	0.00104	0.0613	0.000344
1347.03	271	1662.15	14.7264	0.4907	0.01746	0.0710	0.001091	3348.76	671	1342.54	0.8341	0.8928	0.00105	0.0637	0.000352
1371.34	275	1659.37	14.6298	0.4939	0.01736	0.0712	0.001092	3371.17	676	1347.93	0.7416	0.8850	0.00088	0.0653	0.000337
1396.42	281	1655.46	14.8065	0.4984	0.01761	0.0717	0.001116	3397.60	681	1355.78	0.7598	0.8736	0.00089	0.0677	0.000348
1422.89	286	1651.86	14.9117	0.5026	0.01776	0.0720	0.001136	3420.89	687	1361.29	0.7700	0.8656	0.00090	0.0694	0.000354
1448.88	292	1645.41	15.0156	0.5102	0.01794	0.0723	0.001167	3448.24	691	1370.27	0.7938	0.8527	0.00092	0.0721	0.000368
1472.46	297	1641.40	15.3046	0.5149	0.01831	0.0727	0.001205	3472.84	696	1379.71	0.9275	0.8392	0.00112	0.0749	0.000404
1499.88	302	1634.82	15.6630	0.5227	0.01880	0.0729	0.001256	3498.61	701	1384.67	0.8379	0.8321	0.00096	0.0763	0.000394
1522.75	306	1630.98	15.9538	0.5272	0.01918	0.0732	0.001293	3522.81	706	1390.28	0.8528	0.8241	0.00097	0.0780	0.000402
1548.93	311	1625.16	16.3875	0.5341	0.01976	0.0735	0.001353	3549.68	711	1397.49	0.8772	0.8138	0.00099	0.0803	0.000417
1574.73	316	1615.07	17.2203	0.5461	0.02086	0.0736	0.001463	3572.79	716	1407.66	1.3284	0.7994	0.00169	0.0834	0.000522
1598.23	321	1603.15	18.0358	0.5604	0.02196	0.0736	0.001582	3596.29	721	1409.99	0.9298	0.7962	0.00104	0.0840	0.000447
1622.07	326	1588.30	18.6514	0.5784	0.02287	0.0732	0.001701	3624.68	726	1417.04	0.9513	0.7862	0.00105	0.0862	0.000460
1648.49	331	1572.92	19.1202	0.5971	0.02362	0.0727	0.001814	3649.51	731	1421.95	0.9022	0.7792	0.00094	0.0878	0.000461
1672.68	336	1555.39	19.7536	0.6187	0.02460	0.0719	0.001958	3674.38	736	1433.17	1.2311	0.7634	0.00146	0.0914	0.000545
1699.36	341	1535.71	20.3218	0.6431	0.02555	0.0709	0.002113	3696.83	741	1435.10	0.9570	0.7608	0.00098	0.0919	0.000495
1721.48	346	1516.29	20.6008	0.6675	0.02615	0.0697	0.002245	3720.14	745	1439.76	1.0521	0.7543	0.00114	0.0934	0.000520
1748.69	351	1495.72	20.9765	0.6936	0.02691	0.0683	0.002400	3748.49	751	1445.29	0.9525	0.7465	0.00092	0.0952	0.000515
1772.72	356	1469.06	21.1415	0.7278	0.02749	0.0661	0.002565	3773.13	756	1452.70	1.0403	0.7361	0.00105	0.0977	0.000548
1799.00	361	1444.88	21.1021	0.7593	0.02779	0.0639	0.002700	3797.18	761	1458.39	1.0445	0.7281	0.00104	0.0997	0.000553
1824.08	366	1417.40	20.8420	0.7956	0.02785	0.0610	0.002825	3823.89	766	1462.96	1.0698	0.7217	0.00106	0.1012	0.000568
1846.13	371	1395.80	20.4260	0.8245	0.02763	0.0587	0.002900	3847.16	771	1469.03	1.1018	0.7132	0.00109	0.1033	0.000590
1873.68	376	1375.64	19.9021	0.8518	0.02722	0.0563	0.002951	3873.90	776	1475.59	1.2003	0.7041	0.00124	0.1055	0.000616
1898.39	381	1353.68	19.4772	0.8818	0.02698	0.0536	0.003023	3899.01	781	1479.01	1.0764	0.6993	0.00100	0.1067	0.000602
1922.13	386	1334.37	18.9166	0.9086	0.02650	0.0511	0.003057	3924.74	786	1482.90	1.0699	0.6939	0.00095	0.1080	0.000615
1946.43	391	1320.97	18.2332	0.9274	0.02575	0.0493	0.003039	3947.24	791	1489.98	1.1526	0.6840	0.00105	0.1105	0.000652
1972.73	396	1307.06	17.6629	0.9470	0.02516	0.0473	0.003038	3974.14	796	1496.85	1.3116	0.6745	0.00132	0.1129	0.000690
1995.99	401	1291.59	17.0611	0.9690	0.02454	0.0451	0.003034	3984.40	798	1496.33	1.1754	0.6752	0.00106	0.1129	0.000670

Table E.8: *a*, *b*, and χ, with maximum offsets increasing from 2849.9 m to 3984.4 m, for all receivers, for the longside, longoffsets only, (D+C). Best values (minimum standard error) are highlighted.

Max Offset (m)	# observations	*a*	Standard Error	*b*	Standard Error	χ	Standard Error	Max Offset (m)	# observations	*a*	Standard Error	*b*	Standard Error	χ	Standard Error
2849.91	11	1470.53	90.18	0.6504	0.0686	0.1631	0.04575	3448.24	131	1506.57	10.92	0.5654	0.0175	0.2142	0.00765
2872.44	15	1460.49	69.43	0.6338	0.0584	0.1933	0.03704	3472.84	136	1508.08	14.51	0.5691	0.0237	0.2082	0.01042
2895.99	20	1506.75	50.44	0.5976	0.0467	0.1779	0.02653	3498.61	141	1506.63	13.83	0.5719	0.0228	0.2067	0.01015
2922.93	26	1515.68	38.93	0.5652	0.0398	0.2035	0.02118	3522.81	146	1500.56	13.54	0.5783	0.0226	0.2068	0.01024
2946.35	31	1541.42	32.98	0.5569	0.0358	0.1819	0.01744	3549.68	151	1498.00	13.05	0.5805	0.0220	0.2073	0.01008
2973.59	36	1549.17	29.21	0.5368	0.0331	0.1950	0.01540	3572.79	156	1495.94	17.73	0.5950	0.0309	0.1937	0.01443
2995.88	41	1534.85	26.39	0.5456	0.0316	0.2023	0.01423	3596.29	161	1492.85	17.12	0.5989	0.0303	0.1930	0.01429
3023.06	46	1535.25	23.58	0.5429	0.0293	0.2050	0.01275	3624.68	166	1490.67	16.46	0.6010	0.0294	0.1932	0.01403
3047.19	51	1527.11	21.44	0.5448	0.0275	0.2128	0.01178	3649.51	171	1484.55	16.03	0.6077	0.0291	0.1930	0.01411
3072.06	56	1533.55	20.89	0.5395	0.0274	0.2109	0.01146	3674.38	176	1485.91	19.46	0.6158	0.0362	0.1828	0.01783
3097.79	61	1530.88	18.57	0.5432	0.0250	0.2100	0.01033	3696.83	181	1481.32	18.56	0.6225	0.0352	0.1808	0.01758
3123.28	66	1530.10	18.78	0.5336	0.0255	0.2222	0.01044	3720.14	185	1477.81	18.09	0.6259	0.0346	0.1811	0.01750
3147.80	71	1529.38	17.53	0.5357	0.0242	0.2206	0.00987	3748.49	191	1473.87	17.27	0.6303	0.0336	0.1809	0.01724
3173.84	76	1530.25	16.06	0.5340	0.0225	0.2216	0.00912	3773.13	196	1472.15	17.29	0.6360	0.0343	0.1767	0.01784
3197.66	81	1524.53	15.07	0.5437	0.0216	0.2173	0.00881	3797.18	201	1470.29	16.56	0.6382	0.0333	0.1765	0.01749
3224.52	86	1521.55	14.41	0.5437	0.0209	0.2210	0.00853	3823.89	206	1465.41	15.73	0.6461	0.0323	0.1736	0.01726
3246.31	91	1523.07	13.96	0.5436	0.0205	0.2192	0.00836	3847.16	211	1462.33	15.60	0.6534	0.0328	0.1693	0.01780
3274.71	97	1529.62	13.07	0.5360	0.0193	0.2199	0.00790	3873.90	216	1466.86	15.55	0.6467	0.0327	0.1714	0.01775
3298.23	101	1530.62	12.81	0.5374	0.0191	0.2171	0.00777	3899.01	221	1461.65	15.42	0.6528	0.0330	0.1707	0.01820
3322.80	106	1526.40	12.46	0.5413	0.0188	0.2177	0.00772	3924.74	226	1457.66	14.82	0.6585	0.0323	0.1691	0.01808
3348.76	111	1523.01	12.02	0.5466	0.0184	0.2157	0.00764	3947.24	231	1459.47	14.96	0.6589	0.0331	0.1668	0.01867
3371.17	116	1518.38	12.02	0.5498	0.0186	0.2178	0.00780	3974.14	236	1460.58	15.12	0.6604	0.0340	0.1641	0.01935
3397.60	121	1514.90	11.83	0.5538	0.0185	0.2173	0.00786	3984.40	238	1456.83	14.49	0.6678	0.0333	0.1606	0.01918
3420.89	127	1509.37	11.29	0.5617	0.0180	0.2151	0.00780								

Table E.9: *a*, *b*, and χ, with maximum offsets increasing from 99.6 m to 1014.1 m, for all receivers, for the shortside only, (B). Best values (minimum standard error) are highlighted.

Max Offset (m)	# observations	*a*	Standard Error	*b*	Standard Error	χ	Standard Error	Max Offset (m)	# observations	*a*	Standard Error	*b*	Standard Error	χ	Standard Error
99.57	15	2000.21	55862.29	0.9504	71.2550	0.0002	199.53349	573.81	114	1629.25	13.07	0.5324	0.0157	0.0482	0.00213
119.62	21	2001.32	39254.67	0.9527	50.2985	0.0002	87.70875	599.45	119	1635.28	12.95	0.5251	0.0155	0.0491	0.00197
142.49	26	2000.86	36636.46	0.9517	46.9292	0.0002	56.80207	624.84	124	1631.34	12.59	0.5299	0.0151	0.0485	0.00179
174.10	32	1636.08	21.10	0.5243	0.0253	0.1022	0.04431	646.13	129	1631.04	12.32	0.5302	0.0148	0.0487	0.00165
195.77	37	1645.61	19.20	0.5129	0.0229	0.1039	0.03086	671.18	133	1631.73	12.00	0.5294	0.0144	0.0489	0.00153
224.50	43	1670.40	20.86	0.4837	0.0246	0.0536	0.02132	698.48	139	1629.20	11.59	0.5324	0.0139	0.0486	0.00139
246.71	48	1667.38	20.20	0.4875	0.0239	0.0214	0.01502	722.70	144	1628.59	11.33	0.5331	0.0136	0.0495	0.00130
269.42	52	1666.99	19.23	0.4881	0.0227	0.0121	0.01168	748.24	149	1624.80	11.40	0.5376	0.0137	0.0505	0.00126
297.14	58	1658.56	17.59	0.4980	0.0209	0.0132	0.00868	771.35	154	1624.61	11.43	0.5378	0.0138	0.0517	0.00121
324.69	64	1658.61	16.71	0.4979	0.0198	0.0189	0.00695	798.75	159	1620.55	11.63	0.5426	0.0140	0.0527	0.00120
347.76	68	1650.58	16.24	0.5074	0.0193	0.0197	0.00604	823.75	164	1617.36	12.20	0.5464	0.0147	0.0543	0.00122
373.06	73	1648.99	16.05	0.5092	0.0191	0.0285	0.00536	847.08	169	1620.34	12.38	0.5427	0.0149	0.0557	0.00120
399.63	79	1647.60	15.35	0.5108	0.0183	0.0340	0.00453	872.46	174	1619.21	12.07	0.5440	0.0146	0.0560	0.00114
419.78	83	1643.42	15.04	0.5157	0.0180	0.0370	0.00409	898.67	179	1615.67	12.10	0.5482	0.0146	0.0566	0.00112
444.64	88	1641.72	15.00	0.5176	0.0179	0.0429	0.00374	924.31	184	1613.97	12.45	0.5502	0.0151	0.0578	0.00113
470.94	94	1638.25	14.62	0.5217	0.0175	0.0465	0.00329	949.15	189	1611.46	12.71	0.5531	0.0154	0.0589	0.00114
497.40	99	1638.73	14.05	0.5211	0.0168	0.0481	0.00291	972.73	194	1607.52	13.21	0.5578	0.0160	0.0600	0.00117
519.69	104	1639.54	13.52	0.5201	0.0162	0.0470	0.00257	997.09	199	1608.49	13.58	0.5565	0.0165	0.0612	0.00119
544.98	108	1634.21	13.27	0.5265	0.0159	0.0457	0.00235	1014.08	202	1609.29	13.47	0.5555	0.0163	0.0615	0.00115

Table E.10: *a*, *b*, and χ, with maximum offsets increasing from 69.7 m to 1014.4 m, for all receivers, for the longside, shortoffsets only, (B'). This is the same as Table E.7 up to the offset of 998.0 m, and is included here for comparison with results for the shortside only (B), Table E.9. Best values (minimum standard error) are highlighted.

Max Offset (m)	# observations	a	Standard Error	b	Standard Error	χ	Standard Error	Max Offset (m)	# observations	a	Standard Error	b	Standard Error	χ	Standard Error
69.67	9	2000.06	106137.68	0.9501	135.18087	0.0002	559.65448	549.68	111	1686.14	13.37	0.4645	0.01568	0.0425	0.00224
73.25	10	2000.11	103505.29	0.9503	131.81201	0.0002	485.39942	574.42	116	1685.51	13.70	0.4651	0.01607	0.0463	0.00215
74.74	11	2000.11	87487.30	0.9503	111.17851	0.0002	472.09359	598.16	120	1684.52	13.40	0.4663	0.01573	0.0478	0.00200
93.23	18	2000.55	51761.30	0.9511	65.99247	0.0002	189.62203	624.92	126	1685.58	12.99	0.4650	0.01524	0.0495	0.00179
114.92	23	2000.29	39486.31	0.9506	50.53036	0.0002	89.39587	648.93	131	1684.55	12.55	0.4661	0.01473	0.0503	0.00163
136.23	28	1651.81	22.99	0.5051	0.02731	0.1660	0.08941	674.71	136	1686.16	12.25	0.4642	0.01436	0.0514	0.00150
159.55	33	1664.78	22.81	0.4902	0.02697	0.0079	0.03743	695.53	141	1684.52	11.87	0.4661	0.01393	0.0518	0.00138
185.80	38	1665.18	19.83	0.4898	0.02345	0.0057	0.02389	722.97	146	1686.66	11.59	0.4635	0.01358	0.0524	0.00128
224.32	45	1663.12	17.89	0.4923	0.02117	0.0015	0.01474	747.80	152	1684.10	11.23	0.4665	0.01318	0.0529	0.00118
247.11	50	2004.84	24997.27	0.9612	32.12677	0.0002	11.99789	772.71	156	1686.85	11.25	0.4632	0.01319	0.0540	0.00114
273.34	55	1682.10	17.50	0.4697	0.02054	0.0130	0.01023	799.36	161	1684.63	11.12	0.4658	0.01304	0.0547	0.00108
299.43	61	1677.64	16.70	0.4748	0.01964	0.0280	0.00834	822.94	165	1687.93	11.33	0.4619	0.01328	0.0560	0.00107
324.60	66	1679.46	15.55	0.4726	0.01829	0.0331	0.00679	847.58	171	1684.44	11.92	0.4658	0.01399	0.0578	0.00109
346.83	70	1674.73	14.86	0.4782	0.01751	0.0330	0.00581	873.16	176	1685.82	12.17	0.4641	0.01428	0.0592	0.00108
373.16	75	1678.88	13.97	0.4733	0.01643	0.0337	0.00476	898.70	181	1679.42	12.17	0.4716	0.01432	0.0591	0.00105
396.72	80	1671.75	13.51	0.4817	0.01594	0.0346	0.00406	921.31	185	1686.21	12.53	0.4636	0.01469	0.0602	0.00106
421.11	85	1681.38	13.59	0.4704	0.01597	0.0321	0.00361	947.13	191	1679.45	13.56	0.4714	0.01594	0.0618	0.00112
447.16	90	1677.47	13.05	0.4750	0.01536	0.0322	0.00310	972.35	195	1676.27	13.47	0.4751	0.01586	0.0622	0.00110
473.07	96	1682.65	12.59	0.4689	0.01479	0.0324	0.00264	997.99	202	1674.08	13.43	0.4777	0.01583	0.0617	0.00107
497.01	100	1687.87	13.33	0.4626	0.01562	0.0372	0.00266	1014.40	203	1677.39	13.56	0.4738	0.01597	0.0622	0.00106
523.77	106	1680.75	13.54	0.4709	0.01591	0.0406	0.00244								

APPENDIX F

Forward Modelling

Isotropic and Anisotropic Cases

Table F.1a: Isotropic Case: *a*, and *b* from zero-offset VSP times, receiver at 1974 m.

a = 1592.258651185210		b = 0.575514064006845			$\chi = 0$		z = 1973.923		
offset (m)	p	computed time (ms)	observed time (ms)	residual (ms)	offset (m)	p	computed time (ms)	observed time (ms)	residual (ms)
1014.078	0.000209626510788	1048.740	1036.432	-12.307	1485.368	0.000273040472415	1163.395	1136.798	-26.597
989.797	0.000205712753012	1043.697	1031.409	-12.288	1513.211	0.000276078525991	1171.040	1143.508	-27.532
966.288	0.000201861434798	1038.906	1027.439	-11.467	1539.303	0.000278858977004	1178.280	1149.417	-28.863
941.466	0.000197728989511	1033.947	1023.055	-10.891	1565.130	0.000281548776419	1185.517	1154.933	-30.584
915.969	0.000193413716236	1028.960	1018.204	-10.756	1588.644	0.000283944368610	1192.165	1160.874	-31.291
889.718	0.000188896311053	1023.942	1014.435	-9.507	1612.475	0.000286321211223	1198.960	1167.062	-31.898
864.303	0.000184451094646	1019.197	1010.473	-8.724	1638.883	0.000288895887271	1206.556	1173.549	-33.007
841.107	0.000180332827748	1014.966	1005.947	-9.019	1663.079	0.000291200993883	1213.574	1178.955	-34.619
816.118	0.000175831304874	1010.516	1002.145	-8.371	1689.771	0.000293685063573	1221.380	1185.425	-35.955
788.795	0.000170832978479	1005.780	998.318	-7.462	1711.871	0.000295695786599	1227.893	1191.324	-36.569
765.793	0.000166563833394	1001.900	994.844	-7.055	1739.048	0.000298112092385	1235.962	1197.521	-38.441
740.308	0.000161769058933	997.716	991.292	-6.424	1763.081	0.000300198038172	1243.152	1203.817	-39.335
716.162	0.000157164252031	993.865	987.772	-6.093	1789.370	0.000302425907052	1251.073	1210.837	-40.235
694.514	0.000152985000465	990.508	985.218	-5.290	1814.387	0.000304494673641	1258.665	1217.784	-40.881
663.944	0.000147003342623	985.922	980.535	-5.387	1836.461	0.000306279094921	1265.406	1223.474	-41.932
642.565	0.000142765274082	982.825	977.875	-4.950	1863.985	0.000308451379149	1273.866	1231.080	-42.786
617.231	0.000137686063139	979.272	975.246	-4.027	1888.688	0.000310351817400	1281.509	1235.614	-45.895
591.674	0.000132500320033	975.819	971.165	-4.654	1912.386	0.000312132086319	1288.885	1242.405	-46.480
568.580	0.000127762571806	972.814	968.847	-3.968	1936.696	0.000313915332891	1296.495	1250.340	-46.155
538.050	0.000121425391083	969.010	966.045	-2.965	1962.993	0.000315796344855	1304.775	1255.989	-48.786
515.799	0.000116755354013	966.360	963.125	-3.235	1986.236	0.000317417970578	1312.134	1262.363	-49.771
489.340	0.000111147870939	963.345	960.062	-3.283	2011.513	0.000319138702301	1320.179	1269.025	-51.154
469.040	0.000106806749167	961.133	958.225	-2.908	2038.012	0.000320895641195	1328.659	1276.389	-52.270
444.262	0.000101463990362	958.552	955.686	-2.866	2058.654	0.000322231518234	1335.297	1281.452	-53.845
418.215	0.000095797380544	955.983	953.700	-2.283	2089.406	0.000324169383499	1345.236	1291.095	-54.141
394.946	0.000090693523154	953.813	951.439	-2.375	2113.127	0.000325622329771	1352.943	1297.340	-55.603
373.059	0.000085858578081	951.881	949.506	-2.375	2137.010	0.000327049070906	1360.737	1304.095	-56.642
344.072	0.000079406553017	949.486	948.215	-1.271	2162.001	0.000328503809092	1368.928	1308.005	-60.923
324.116	0.000074934387020	947.946	946.461	-1.485	2190.353	0.000330107893497	1378.265	1318.307	-59.958
297.101	0.000068843303390	946.003	944.746	-1.258	2208.538	0.000331111299404	1384.277	1324.103	-60.174
275.418	0.000063925608551	944.564	943.693	-0.871	2240.131	0.000332808083626	1394.765	1332.692	-62.073
246.708	0.000057377986764	942.823	941.976	-0.847	2262.848	0.000333992490758	1402.339	1340.505	-61.834
225.285	0.000052467204414	941.646	940.090	-1.556	2285.069	0.000335122655714	1409.773	1346.629	-63.144
201.211	0.000046925935798	940.450	938.334	-2.116	2313.522	0.000336529579747	1419.328	1354.231	-65.098
182.634	0.000042634846920	939.618	937.775	-1.843	2338.818	0.000337743237750	1427.857	1361.689	-66.168
151.037	0.000035309403062	938.386	937.281	-1.105	2364.031	0.000338918806965	1436.387	1368.898	-67.489
136.395	0.000031904729124	937.894	936.890	-1.004	2387.757	0.000339994557160	1444.441	1376.166	-68.275
119.615	0.000027996108001	937.392	936.139	-1.252	2414.140	0.000341156703928	1453.427	1384.134	-69.293
94.406	0.000022112190426	936.760	935.931	-0.829	2438.493	0.000342198223774	1461.748	1389.482	-72.265
82.931	0.000019429920059	936.522	935.126	-1.396	2462.794	0.000343208213368	1470.076	1396.500	-73.576
76.916	0.000018022874721	936.409	935.534	-0.875	2487.398	0.000344201529301	1478.532	1404.673	-73.860
74.741	0.000017514173288	936.370	935.336	-1.034	2515.010	0.000345281925905	1488.051	1412.021	-76.030
84.530	0.000019803744752	936.553	935.707	-0.846	2538.668	0.000346179314054	1496.231	1420.411	-75.820
93.234	0.000021838229930	936.734	935.612	-1.122	2561.908	0.000347035844531	1504.286	1425.506	-78.780
112.705	0.000026384628382	937.204	936.244	-0.960	2586.946	0.000347931491599	1512.986	1432.678	-80.308
130.648	0.000030566860275	937.715	936.110	-1.605	2611.466	0.000348781819693	1521.528	1439.409	-82.119
152.613	0.000035675374875	938.442	937.377	-1.065	2634.472	0.000349555971584	1529.561	1447.930	-81.631
176.332	0.000041176261923	939.354	938.209	-1.145	2664.740	0.000350540315272	1540.156	1457.009	-83.147
200.664	0.000046799768760	940.424	939.183	-1.241	2693.145	0.000351429522220	1550.126	1465.913	-84.213
222.033	0.000051720050685	941.477	940.566	-0.910	2713.475	0.000352045802922	1557.277	1471.688	-85.589
244.406	0.000056851246758	942.691	941.458	-1.233	2737.504	0.000352752953709	1565.745	1478.316	-87.428
270.447	0.000062794840792	944.249	942.481	-1.768	2763.498	0.000353492518121	1574.924	1486.156	-88.768
293.032	0.000067922329921	945.725	944.033	-1.692	2790.900	0.000354244106167	1584.621	1492.776	-91.844
317.805	0.000073515157967	947.477	945.562	-1.915	2818.515	0.000354973041329	1594.413	1501.544	-92.870
343.415	0.000079259679969	949.434	947.720	-1.714	2840.130	0.000355524048414	1602.092	1509.010	-93.083
369.719	0.000085117773141	951.596	949.464	-2.132	2867.558	0.000356198979065	1611.853	1516.612	-95.241
393.092	0.000090285176192	953.646	952.038	-1.607	2891.097	0.000356757016326	1620.244	1522.475	-97.769
417.457	0.000095631799683	955.911	953.379	-2.532	2913.083	0.000357260903740	1628.093	1527.969	-100.124
443.392	0.000101275664359	958.464	956.346	-2.118	2936.480	0.000357779042726	1636.458	1537.739	-98.719
465.151	0.000105971318631	960.719	958.015	-2.704	2963.685	0.000358358548188	1646.199	1544.497	-101.703
493.184	0.000111966207102	963.774	960.078	-3.696	2985.984	0.000358815444206	1654.195	1551.710	-102.485
515.711	0.000116736856689	966.350	963.346	-3.004	3013.154	0.000359350587250	1663.952	1560.112	-103.840
541.511	0.000122147970816	969.432	965.572	-3.860	3037.280	0.000359806302820	1672.627	1566.471	-106.156
566.218	0.000127275170053	972.513	968.150	-4.363	3062.143	0.000360257147213	1681.578	1575.806	-105.773
594.084	0.000132992016333	976.139	971.846	-4.293	3087.867	0.000360703926690	1690.852	1582.710	-108.142
616.525	0.000137543559703	979.175	974.437	-4.738	3113.355	0.000361127256734	1700.051	1587.800	-112.250
640.390	0.000142331796852	982.515	977.709	-4.806	3137.870	0.000361516610007	1708.909	1597.852	-111.057
666.096	0.000147427456545	986.239	980.848	-5.392	3163.910	0.000361911429848	1718.328	1605.218	-113.110
686.674	0.000151459977853	989.315	983.892	-5.423	3187.722	0.000362255893360	1726.949	1614.170	-112.779
714.131	0.000156774081808	993.546	987.625	-5.921	3214.578	0.000362625771713	1736.683	1620.041	-116.642
734.065	0.000160584108069	996.709	990.735	-5.974	3236.351	0.000362911421257	1744.582	1627.195	-117.387
763.765	0.000166184731295	1001.562	994.462	-7.100	3259.675	0.000363203549890	1753.050	1634.435	-118.615
790.341	0.000171117904770	1006.044	998.943	-7.102	3288.287	0.000363542720650	1763.447	1645.422	-118.025
818.537	0.000176270107662	1010.942	1002.359	-8.583	3312.831	0.000363817131210	1772.373	1651.273	-121.100
838.613	0.000179886651085	1014.517	1006.107	-8.411	3338.804	0.000364091250199	1781.826	1660.710	-121.116
864.183	0.000184429936038	1019.175	1009.904	-9.271	3361.215	0.000364314570419	1789.988	1665.429	-124.560
889.644	0.000188883511549	1023.928	1015.459	-8.469	3387.640	0.000364562494942	1799.618	1674.863	-124.756
916.870	0.000193567460605	1029.134	1018.333	-10.801	3405.836	0.000364723685071	1806.253	1681.033	-125.220
938.114	0.000197165725279	1033.285	1022.636	-10.649	3438.279	0.000364992211526	1818.091	1690.683	-127.408
967.871	0.000202122749139	1039.226	1028.093	-11.132	3462.882	0.000365180023102	1827.073	1698.660	-128.413
984.094	0.000204783997508	1042.526	1032.088	-10.438	3488.647	0.000365362401889	1836.484	1706.745	-129.740
1014.404	0.000209678525085	1048.808	1035.925	-12.883	3512.857	0.000365520683268	1845.331	1712.753	-132.579
1043.220	0.000214237995609	1054.916	1041.995	-12.921	3539.715	0.000365681738208	1855.151	1720.417	-134.734
1065.184	0.000217651641596	1059.659	1046.384	-13.275	3562.825	0.000365808315594	1863.603	1742.573	-121.031
1088.895	0.000221277499328	1064.863	1050.471	-14.392	3586.331	0.000365925886028	1872.203	1738.627	-133.576
1115.015	0.000225200240718	1070.694	1055.210	-15.484	3614.704	0.000366053073022	1882.588	1743.987	-138.600
1140.098	0.000228897216714	1076.389	1060.235	-16.154	3639.544	0.000366151465696	1891.682	1750.378	-141.304
1165.295	0.000232541993109	1082.203	1065.256	-16.947	3664.411	0.000366238089847	1900.788	1773.884	-126.904
1187.085	0.000235638608266	1087.304	1070.389	-16.915	3686.858	0.000366306271990	1909.009	1767.780	-141.229
1214.352	0.000239441588880	1093.781	1075.694	-18.087	3715.162	0.000366378966172	1919.378	1773.923	-145.455
1238.248	0.000242709230031	1099.542	1080.502	-19.040	3738.511	0.000366427998517	1927.934	1782.683	-145.251
1262.578	0.000245973831549	1105.487	1085.769	-19.718	3763.146	0.000366469222852	1936.961	1802.645	-134.316
1288.093	0.000249330486829	1111.806	1092.119	-19.687	3787.190	0.000366499247701	1945.773	1796.954	-148.819
1312.260	0.000252447140056	1117.869	1097.591	-20.278	3813.895	0.000366521000192	1955.561	1807.817	-147.744
1337.566	0.000255645941468	1124.298	1102.887	-21.411	3837.164	0.000366530195032	1964.089	1825.078	-139.011
1366.579	0.000259232563500	1131.767	1110.075	-21.692	3863.906	0.000366529760465	1973.891	1823.494	-150.397
1386.806	0.000261682557685	1137.036	1113.877	-23.159	3889.009	0.000366518852511	1983.092	1820.780	-162.312
1413.235	0.000264822017037	1143.993	1120.171	-23.823	3914.736	0.000366497334259	1992.521	1833.245	-159.277
1434.249	0.000267268749088	1149.584	1125.078	-24.506	3937.224	0.000366470114092	2000.762	1860.562	-140.201
1457.820	0.000269961653160	1155.916	1129.865	-26.051	3964.125	0.000366427444571	2010.620	1870.558	-140.062

Table F.1b: Isotropic Case: *a*, and *b* from zero-offset VSP times, receiver at 2014 m.

a = 1592.258651185210		b = 0.575514064006845			x = 0		z = 2013.927		
offset (m)	p	computed time (ms)	observed time (ms)	residual (ms)	offset (m)	p	computed time (ms)	observed time (ms)	residual (ms)
991.550	0.000201654230831	1056.171	1044.546	-11.625	1504.896	0.000270299158992	1178.452	1152.406	-26.046
967.175	0.000197716966781	1051.303	1039.433	-11.870	1532.702	0.000273277453099	1186.009	1159.518	-26.491
943.576	0.000193845400315	1046.683	1035.737	-10.946	1558.966	0.000276026059265	1193.223	1164.752	-28.471
918.726	0.000189705387838	1041.917	1031.620	-10.297	1584.736	0.000278662849997	1200.370	1170.728	-29.642
893.046	0.000185359168315	1037.101	1027.395	-9.706	1608.206	0.000281013068368	1206.938	1176.191	-30.747
866.861	0.000180856782854	1032.306	1023.883	-8.424	1632.059	0.000283352466466	1213.669	1182.031	-31.639
841.491	0.000176426853083	1027.774	1019.800	-7.974	1658.491	0.000285887348787	1221.192	1188.399	-32.794
818.125	0.000172288121928	1023.700	1015.300	-8.400	1682.662	0.000288153537308	1228.130	1193.896	-34.233
793.125	0.000167798605938	1019.449	1011.754	-7.694	1709.332	0.000290597333961	1235.848	1200.831	-35.017
765.709	0.000162802777077	1014.917	1008.324	-6.593	1731.466	0.000292580881624	1242.302	1206.627	-35.675
742.569	0.000158527757133	1011.199	1004.757	-6.442	1758.713	0.000294967979608	1250.306	1212.206	-38.100
717.025	0.000153747415346	1007.210	1001.513	-5.697	1782.727	0.000297022573371	1257.414	1218.930	-38.484
692.777	0.000149151206006	1003.538	998.272	-5.266	1809.004	0.000299218891144	1265.249	1224.991	-40.257
671.179	0.000145009977834	1000.361	995.647	-4.714	1834.144	0.000301270004102	1272.797	1232.119	-40.678
640.407	0.000139034242110	995.990	991.688	-4.302	1856.165	0.000303027049826	1279.450	1237.956	-41.494
619.158	0.000134857064448	993.080	988.858	-4.222	1883.729	0.000305175142529	1287.833	1244.659	-43.173
593.758	0.000129810849718	989.719	986.490	-3.229	1908.443	0.000307053492485	1295.398	1250.987	-44.411
568.106	0.000124657005285	986.455	982.274	-4.181	1932.226	0.000308819142825	1302.722	1257.720	-45.001
544.979	0.000119962388498	983.626	980.074	-3.553	1956.508	0.000310580263369	1310.242	1264.184	-46.058
513.842	0.000113571816005	979.990	977.187	-2.803	1982.824	0.000312442202163	1318.440	1270.513	-47.927
491.551	0.000108949207262	977.510	974.652	-2.858	2006.097	0.000314048979787	1325.730	1276.609	-49.121
465.116	0.000103417595348	974.703	971.956	-2.747	2031.400	0.000315754292660	1333.698	1283.866	-49.832
444.635	0.000099096192246	972.629	970.103	-2.527	2057.867	0.000317492382963	1342.078	1290.939	-51.140
419.775	0.000093810548193	970.231	967.793	-2.438	2078.568	0.000318819860907	1348.664	1296.333	-52.332
393.803	0.000088243082683	967.867	966.024	-1.843	2109.336	0.000320742056822	1358.504	1305.118	-53.386
370.105	0.000083125024313	965.836	963.975	-1.862	2133.030	0.000322181538855	1366.121	1311.261	-54.860
347.762	0.000078267646663	964.033	962.375	-1.658	2156.926	0.000323598085087	1373.837	1317.697	-56.140
318.675	0.000071900512275	961.849	960.815	-1.035	2181.962	0.000325044877507	1381.956	1322.426	-59.531
297.136	0.000067155731989	960.352	959.260	-1.092	2210.257	0.000326634989862	1391.176	1332.953	-58.223
269.418	0.000061015371498	958.575	957.826	-0.749	2228.452	0.000327632712373	1397.128	1338.401	-58.727
246.599	0.000055933009608	957.241	956.764	-0.477	2260.084	0.000329321835536	1407.519	1346.712	-60.806
217.658	0.000049455363624	955.716	955.323	-0.393	2282.716	0.000330495669237	1414.985	1353.271	-61.714
195.765	0.000044533612892	954.687	953.803	-0.884	2304.890	0.000331618204253	1422.326	1359.676	-62.650
170.528	0.000038839556756	953.635	952.296	-1.339	2333.394	0.000333021810186	1431.799	1367.060	-64.739
150.322	0.000034266629687	952.896	951.830	-1.066	2358.739	0.000334233378210	1440.254	1375.573	-64.681
119.158	0.000027192651614	951.938	951.246	-0.692	2383.962	0.000335405752374	1448.700	1382.318	-66.381
100.035	0.000022841226068	951.460	951.140	-0.320	2407.702	0.000336479328248	1456.675	1389.120	-67.556
80.477	0.000018383974152	951.057	950.595	-0.462	2434.097	0.000337639588051	1465.572	1396.500	-69.072
52.512	0.000012001658523	950.632	950.060	-0.572	2458.515	0.000338682213284	1473.829	1403.233	-70.596
39.174	0.000008954579994	950.492	949.748	-0.744	2482.793	0.000339690192838	1482.064	1410.509	-71.555
37.125	0.000008486544180	950.474	949.931	-0.543	2507.442	0.000340684849684	1490.449	1418.106	-72.343
47.917	0.000010952180102	950.579	949.852	-0.727	2535.041	0.000341764858031	1499.867	1425.056	-74.811
67.679	0.000015464442129	950.840	950.437	-0.403	2558.701	0.000342662950462	1507.964	1432.211	-75.752
87.531	0.000019992276363	951.192	950.647	-0.545	2581.986	0.000343522230169	1515.953	1439.055	-76.897
114.917	0.000026228093567	951.825	951.544	-0.282	2607.071	0.000344421168892	1524.581	1445.480	-79.101
136.226	0.000031069725271	952.436	951.374	-1.062	2631.588	0.000345273427934	1533.036	1452.599	-80.437
159.548	0.000036356003525	953.222	953.025	-0.197	2654.653	0.000346051893993	1541.009	1459.835	-81.174
185.804	0.000042288614041	954.254	953.865	-0.389	2684.768	0.000347034936226	1551.445	1469.199	-82.246
210.975	0.000047954817646	955.390	954.950	-0.440	2713.012	0.000347923289636	1561.259	1477.709	-83.550
234.325	0.000053189944397	956.571	956.605	0.034	2733.279	0.000348541117430	1568.317	1482.503	-85.814
258.040	0.000058484066587	957.895	957.373	-0.522	2757.260	0.000349251339863	1576.684	1489.196	-87.487
284.557	0.000064373775815	959.524	958.386	-1.139	2783.262	0.000349996397694	1585.775	1497.292	-88.483
307.433	0.000069427119884	961.055	960.111	-0.944	2810.670	0.000350754118207	1595.378	1504.319	-91.059
332.872	0.000075014204935	962.892	961.630	-1.262	2838.309	0.000351490114152	1605.082	1512.353	-92.729
359.049	0.000080725201492	964.931	963.944	-0.987	2859.972	0.000352047648319	1612.703	1519.220	-93.484
385.343	0.000086420036538	967.128	965.418	-1.711	2887.458	0.000352731018909	1622.389	1526.834	-95.555
409.334	0.000091577840458	969.263	968.447	-0.816	2911.043	0.000353296438764	1630.715	1534.916	-95.799
433.705	0.000096777668905	971.559	969.921	-1.638	2933.070	0.000353807304714	1638.502	1540.726	-97.777
460.001	0.000102341232115	974.177	972.838	-1.339	2956.504	0.000354332932084	1646.800	1548.725	-98.075
482.029	0.000106962879498	976.482	974.457	-2.026	2983.778	0.000354921903137	1656.472	1555.046	-101.426
509.907	0.000112758757131	979.545	976.609	-2.936	3006.069	0.000355385385485	1664.388	1562.470	-101.918
532.777	0.000117467388266	982.178	979.967	-2.211	3033.245	0.000355929154720	1674.054	1570.417	-103.637
558.748	0.000122762862688	985.297	981.933	-3.364	3057.374	0.000356392720973	1682.648	1578.054	-104.594
583.493	0.000127755327122	988.397	985.107	-3.290	3082.250	0.000356852023393	1691.519	1585.655	-105.864
611.554	0.000133352457400	992.061	988.531	-3.530	3107.982	0.000357307691308	1700.708	1593.522	-107.186
634.129	0.000137804378585	995.121	991.086	-4.036	3133.483	0.000357740091443	1709.825	1600.080	-109.745
658.248	0.000142509594395	998.502	994.422	-4.080	3158.005	0.000358138275207	1718.602	1608.654	-109.948
684.072	0.000147487432181	1002.247	997.434	-4.812	3184.048	0.000358542597735	1727.935	1615.445	-112.490
705.124	0.000151498705644	1005.394	1000.876	-4.518	3207.868	0.000358895987545	1736.479	1623.756	-112.723
732.526	0.000156655815877	1009.616	1004.018	-5.597	3234.734	0.000359276123764	1746.127	1630.595	-115.532
752.696	0.000160405145571	1012.814	1007.432	-5.381	3256.536	0.000359570484031	1753.963	1639.147	-114.816
782.323	0.000165839249081	1017.647	1011.254	-6.392	3279.827	0.000359871242992	1762.341	1646.444	-115.897
809.041	0.000170664219685	1022.142	1015.565	-6.577	3308.451	0.000360221850748	1772.647	1654.579	-118.068
837.034	0.000175641750321	1026.989	1019.073	-7.916	3333.029	0.000360506468255	1781.504	1662.212	-119.292
857.170	0.000179172428149	1030.562	1022.852	-7.709	3358.978	0.000360790844668	1790.863	1669.892	-120.971
882.753	0.000183597811860	1035.202	1026.294	-8.908	3381.389	0.000361023356402	1798.951	1674.585	-124.366
908.363	0.000187959876470	1039.960	1031.885	-8.075	3407.830	0.000361282391350	1808.500	1683.330	-125.171
935.422	0.000192494075601	1045.108	1034.363	-10.744	3426.021	0.000361451161074	1815.074	1689.103	-125.971
956.725	0.000196009828084	1049.246	1038.713	-10.532	3458.467	0.000361733432202	1826.806	1699.251	-127.556
986.543	0.000200850632184	1055.163	1044.700	-10.463	3483.057	0.000361931661190	1835.704	1707.174	-128.529
1002.868	0.000203461149748	1058.463	1049.014	-9.449	3508.829	0.000362125208143	1845.034	1714.270	-130.763
1033.179	0.000208233427637	1064.703	1052.495	-12.208	3533.031	0.000362293972690	1853.800	1721.476	-132.325
1061.975	0.000212677483578	1070.763	1058.421	-12.343	3559.898	0.000362466863361	1863.536	1730.402	-133.134
1084.068	0.000216027700199	1075.499	1062.677	-12.822	3583.016	0.000362603689227	1871.917	1738.836	-133.081
1107.805	0.000219569950860	1080.669	1066.960	-13.709	3606.516	0.000362731667683	1880.440	1744.451	-135.989
1133.931	0.000223400352303	1086.456	1071.377	-15.079	3634.919	0.000362871687775	1890.745	1752.517	-138.228
1159.036	0.000227013679463	1092.110	1076.518	-15.592	3659.735	0.000362981141564	1899.751	1760.693	-139.059
1184.402	0.000230597790250	1097.914	1081.816	-16.098	3684.612	0.000363079045760	1908.782	1767.779	-141.003
1206.284	0.000233636186152	1102.993	1087.232	-15.761	3707.066	0.000363157447179	1916.936	1774.926	-142.010
1233.606	0.000237360489681	1109.428	1092.486	-16.942	3735.376	0.000363243068923	1927.218	1785.556	-141.662
1257.536	0.000240559553266	1115.146	1096.881	-18.265	3758.721	0.000363302785873	1935.699	1792.247	-143.452
1281.929	0.000243760571804	1121.053	1102.535	-18.518	3783.360	0.000363355345322	1944.651	1799.150	-145.500
1307.463	0.000247046845991	1127.319	1108.661	-18.659	3807.424	0.000363396492735	1953.395	1805.479	-147.916
1331.536	0.000250085270971	1133.303	1113.833	-19.470	3834.131	0.000363430599912	1963.101	1814.840	-148.260
1356.935	0.000253228763527	1139.695	1119.047	-20.649	3857.404	0.000363450592718	1971.559	1823.009	-148.550
1386.199	0.000256771713937	1147.158	1125.490	-21.668	3884.155	0.000363462598252	1981.282	1829.612	-151.671
1406.463	0.000259176316268	1152.385	1130.003	-22.382	3909.264	0.000363463391004	1990.408	1837.849	-152.560
1432.981	0.000262263074019	1159.299	1136.112	-23.188	3935.005	0.000363453881500	1999.764	1845.303	-154.461
1453.941	0.000264655492366	1164.821	1141.041	-23.780	3957.499	0.000363437174345	2007.939	1852.544	-155.395
1477.524	0.000267297572149	1171.094	1145.902	-25.192	3984.399	0.000363407107870	2017.715	1860.716	-156.999

Table F.2a: Inhomogeneous Isotropic Case: Forward modelling using *a*, and *b* estimates obtained from offset VSP times for segment 1 with receiver at 1974 m.

a = 1677.328397137130		b = 0.475435538665			z = 0		z = 1973.923		
offset (m)	p	computed time (ms)	observed time (ms)	residual (ms)	offset (m)	p	computed time (ms)	observed time (ms)	residual (ms)
84.530	0.000019930563972	935.498	935.707	0.209	2011.513	0.000324550345872	1323.510	1269.025	-54.485
93.234	0.000021978170725	935.680	935.612	-0.068	2038.012	0.000326422240018	1332.135	1276.389	-55.747
112.705	0.000026553994418	936.153	936.244	0.091	2058.654	0.000327848350200	1338.888	1281.452	-57.437
130.648	0.000030763440395	936.667	936.110	-0.557	2089.406	0.000329921729814	1349.002	1291.095	-57.907
152.613	0.000035905420261	937.399	937.377	-0.022	2113.127	0.000331480089716	1356.847	1297.340	-59.507
176.332	0.000041442663785	938.316	938.209	-0.108	2137.010	0.000333013727286	1364.782	1304.095	-60.687
200.664	0.000047103736030	939.394	939.183	-0.211	2162.001	0.000334581121556	1373.124	1308.005	-65.119
222.033	0.000052057261935	940.453	940.566	0.113	2190.353	0.000336313993129	1382.635	1318.307	-64.328
244.406	0.000057223546398	941.676	941.458	-0.218	2208.538	0.000337400541689	1388.760	1324.103	-64.658
270.447	0.000063208380075	943.244	942.481	-0.763	2240.131	0.000339242746572	1399.449	1332.692	-66.757
293.032	0.000068372014663	944.730	944.033	-0.697	2262.848	0.000340532479505	1407.170	1340.505	-66.666
317.805	0.000074004929848	946.493	945.562	-0.931	2285.069	0.000341766268193	1414.751	1346.629	-68.122
343.415	0.000079791412462	948.463	947.720	-0.743	2313.522	0.000343306725394	1424.497	1354.231	-70.267
369.719	0.000085693193003	950.639	949.464	-1.176	2338.818	0.000344639884931	1433.199	1361.689	-71.510
393.092	0.000090899949778	952.703	952.038	-0.665	2364.031	0.000345935282290	1441.904	1368.898	-73.007
417.457	0.000096288163738	954.984	953.379	-1.605	2387.757	0.000347124437122	1450.126	1376.166	-73.960
443.392	0.000101976967573	957.555	956.346	-1.209	2414.140	0.000348413401834	1459.302	1384.134	-75.168
465.151	0.000106710881291	959.825	958.015	-1.810	2438.493	0.000349572636954	1467.801	1389.482	-78.318
493.184	0.000112755849300	962.902	960.078	-2.824	2462.794	0.000350700700727	1476.309	1396.500	-79.810
515.711	0.000117567408303	965.496	963.346	-2.150	2487.398	0.000351814169023	1484.952	1404.673	-80.279
541.511	0.000123026137654	968.600	965.572	-3.028	2515.010	0.000353030117487	1494.683	1412.021	-82.662
566.218	0.000128199722330	971.703	968.150	-3.553	2538.668	0.000354044234360	1503.047	1420.411	-82.636
594.084	0.000133969844648	975.356	971.846	-3.510	2561.908	0.000355015937246	1511.286	1425.506	-85.780
616.525	0.000138565053558	978.414	974.437	-3.978	2586.946	0.000356036222520	1520.188	1432.678	-87.510
640.390	0.000143400497382	981.779	977.709	-4.071	2611.466	0.000357009152470	1528.930	1439.409	-89.521
666.096	0.000148547911278	985.532	980.848	-4.684	2634.472	0.000357898807661	1537.154	1447.930	-89.224
686.674	0.000152622561419	988.631	983.892	-4.739	2664.740	0.000359035793435	1548.004	1457.009	-90.994
714.131	0.000157993860172	992.895	987.625	-5.270	2693.145	0.000360068930668	1558.217	1465.913	-92.304
734.065	0.000161846130831	996.083	990.735	-5.348	2713.475	0.000360788614433	1565.545	1471.688	-93.857
763.765	0.000167510844044	1000.974	994.462	-6.512	2737.504	0.000361618387686	1574.224	1478.316	-95.907
790.341	0.000172502551940	1005.492	998.943	-6.550	2763.498	0.000362491089837	1583.635	1486.156	-97.479
818.537	0.000177718108531	1010.430	1002.359	-8.071	2790.900	0.000363383554890	1593.580	1492.776	-100.804
838.613	0.000181380556436	1014.035	1006.107	-7.928	2818.515	0.000364254990433	1603.627	1501.544	-102.084
864.183	0.000185983280718	1018.731	1009.904	-8.827	2840.130	0.000364917895020	1611.508	1509.010	-102.499
889.644	0.000190497141303	1023.525	1015.459	-8.066	2867.558	0.000365735244114	1621.528	1516.612	-104.916
916.870	0.000195246780085	1028.776	1018.333	-10.443	2891.097	0.000366415880679	1630.145	1522.475	-107.670
938.114	0.000198897189801	1032.962	1022.636	-10.327	2913.083	0.000367034582484	1638.208	1527.969	-110.239
967.871	0.000203928584229	1038.956	1028.093	-10.863	2936.480	0.000367675207926	1646.803	1537.739	-109.064
984.094	0.000206631032635	1042.286	1032.088	-10.198	2963.685	0.000368397522701	1656.816	1544.497	-112.319
1014.404	0.000211603790583	1048.625	1035.925	-12.700	2985.984	0.000368971762214	1665.037	1551.710	-113.327
1043.220	0.000216239160838	1054.790	1041.995	-12.795	3013.154	0.000369650226760	1675.071	1560.112	-114.960
1065.184	0.000219711658669	1059.577	1046.384	-13.193	3037.280	0.000370233509600	1683.996	1566.471	-117.526
1088.895	0.000223402032908	1064.831	1050.471	-14.360	3062.143	0.000370816099494	1693.209	1575.806	-117.403
1115.015	0.000227397025451	1070.718	1055.210	-15.509	3087.867	0.000371399474847	1702.755	1582.710	-120.046
1140.098	0.000231164557517	1076.470	1060.235	-16.235	3113.355	0.000371958420074	1712.229	1587.800	-124.428
1165.295	0.000234881367003	1082.341	1065.256	-17.085	3137.870	0.000372478452282	1721.354	1597.852	-123.502
1187.085	0.000238041214735	1087.494	1070.389	-17.105	3163.910	0.000373012323649	1731.060	1605.218	-125.842
1214.352	0.000241924548532	1094.037	1075.694	-18.344	3187.722	0.000373484150405	1739.948	1614.170	-125.778
1238.248	0.000245263735162	1099.859	1080.502	-19.357	3214.578	0.000373997898198	1749.985	1620.041	-129.944
1262.578	0.000248602256309	1105.867	1085.769	-20.098	3236.351	0.000374400347689	1758.133	1627.195	-130.937
1288.093	0.000252037599000	1112.254	1092.119	-20.135	3259.675	0.000374817742467	1766.870	1634.435	-132.435
1312.260	0.000255229883689	1118.383	1097.591	-20.793	3288.287	0.000375310782665	1777.601	1645.422	-132.179
1337.566	0.000258509027625	1124.884	1102.887	-21.997	3312.831	0.000375717338292	1786.818	1651.273	-135.545
1366.579	0.000262189198660	1132.438	1110.075	-22.362	3338.804	0.000376131444993	1796.582	1660.710	-135.872
1386.806	0.000264705318933	1137.766	1113.877	-23.890	3361.215	0.000376475658503	1805.015	1665.429	-139.587
1413.235	0.000267932300706	1144.805	1120.171	-24.634	3387.640	0.000376866248460	1814.969	1674.863	-140.106
1434.249	0.000270449524018	1150.462	1125.078	-25.384	3405.836	0.000377125737266	1821.829	1681.033	-140.795
1457.820	0.000273222444046	1156.870	1129.865	-27.005	3438.279	0.000377569647493	1834.071	1690.683	-143.388
1485.368	0.000276396038049	1164.440	1136.798	-27.642	3462.882	0.000377890537346	1843.364	1698.660	-144.704
1513.211	0.000279531258627	1172.180	1143.508	-28.672	3488.647	0.000378212346837	1853.105	1706.745	-146.360
1539.303	0.000282404008071	1179.511	1149.417	-30.094	3512.857	0.000378501684696	1862.265	1712.753	-149.512
1565.130	0.000285186346946	1186.840	1154.933	-31.908	3539.715	0.000378808167492	1872.435	1720.417	-152.018
1588.644	0.000287667201401	1193.575	1160.874	-32.701	3562.825	0.000379059901384	1881.192	1742.573	-138.619
1612.475	0.000290131434502	1200.460	1167.062	-33.398	3586.331	0.000379304781676	1890.105	1738.627	-151.478
1638.883	0.000292804092720	1208.158	1173.549	-34.609	3614.704	0.000379585630374	1900.871	1743.987	-156.884
1663.079	0.000295200016139	1215.271	1178.955	-36.316	3639.544	0.000379818537269	1910.303	1750.378	-159.925
1689.771	0.000297785418469	1223.186	1185.425	-37.761	3664.411	0.000380039792885	1919.751	1773.884	-145.867
1711.871	0.000299880944370	1229.790	1191.324	-38.466	3686.858	0.000380229472715	1928.283	1767.780	-160.504
1739.048	0.000302402640500	1237.974	1197.521	-40.454	3715.162	0.000380455308807	1939.049	1773.923	-165.125
1763.081	0.000304582797136	1245.268	1203.817	-41.451	3738.511	0.000380630614204	1947.934	1782.683	-165.251
1789.370	0.000306914790088	1253.306	1210.837	-42.469	3763.146	0.000380804995005	1957.313	1802.645	-154.668
1814.387	0.000309083674552	1261.011	1217.784	-43.228	3787.190	0.000380964906670	1966.471	1796.954	-169.517
1836.461	0.000310957257565	1267.855	1223.474	-44.381	3813.895	0.000381130813755	1976.647	1807.817	-168.830
1863.985	0.000313241794592	1276.445	1231.080	-45.366	3837.164	0.000381265513355	1985.517	1825.078	-160.439
1888.688	0.000315243974708	1284.208	1235.614	-48.594	3863.906	0.000381409194801	1995.715	1823.494	-172.221
1912.386	0.000317122725858	1291.701	1242.405	-49.296	3889.009	0.000381533437550	2005.291	1820.780	-184.511
1936.696	0.000319007874577	1299.433	1250.340	-49.093	3914.736	0.000381650279553	2015.108	1833.245	-181.864
1962.993	0.000321000115162	1307.849	1255.989	-51.860	3937.224	0.000381743870707	2023.692	1860.562	-163.130
1986.236	0.000322720895482	1315.330	1262.363	-52.967	3964.125	0.000381845550880	2033.962	1870.558	-163.404

Table F.2b: Inhomogeneous Isotropic Case: Forward modelling using a, and b estimates obtained from offset VSP times for segment 1 with receiver at 2014 m.

a = 1677.328397137130		b = 0.475435538665			χ = 0		z = 2013.927		
offset (m)	p	computed time (ms)	observed time (ms)	residual (ms)	offset (m)	p	computed time (ms)	observed time (ms)	residual (ms)
47.917	0.000011032028389	950.157	949.852	-0.305	2031.400	0.000321410852292	1338.012	1283.866	-54.146
67.679	0.000015577283710	950.420	950.437	0.017	2057.867	0.000323263811768	1346.543	1290.939	-55.604
87.531	0.000020138324322	950.775	950.647	-0.127	2078.568	0.000324681780021	1353.249	1296.333	-56.917
114.917	0.000026420090874	951.412	951.544	0.131	2109.336	0.000326739506013	1363.271	1305.118	-58.153
136.226	0.000031297616721	952.027	951.374	-0.653	2133.030	0.000328284180910	1371.031	1311.261	-59.771
159.548	0.000036623350588	952.819	953.025	0.205	2156.926	0.000329807533454	1378.894	1317.697	-61.198
185.804	0.000042600629033	953.860	953.865	0.006	2181.962	0.000331366981752	1387.171	1322.426	-64.745
210.975	0.000048309940268	955.004	954.950	-0.054	2210.257	0.000333085335985	1396.571	1332.953	-63.618
234.325	0.000053585336996	956.193	956.605	0.411	2228.452	0.000334166031848	1402.642	1338.401	-64.240
258.040	0.000058920667606	957.527	957.373	-0.154	2260.084	0.000336000324081	1413.241	1346.712	-66.529
284.557	0.000064856859114	959.169	958.386	-0.783	2282.716	0.000337278732176	1420.860	1353.271	-67.589
307.433	0.000069950676092	960.711	960.111	-0.600	2304.890	0.000338504287601	1428.353	1359.676	-68.676
332.872	0.000075583207582	962.562	961.630	-0.932	2333.394	0.000340041119443	1438.023	1367.060	-70.963
359.049	0.000081341486962	964.616	963.944	-0.672	2358.739	0.000341371887159	1446.658	1375.573	-71.085
385.343	0.000087084381166	966.830	965.418	-1.413	2383.962	0.000342663568529	1455.285	1382.318	-72.967
409.334	0.000092286563100	968.982	968.447	-0.535	2407.702	0.000343850041913	1463.434	1389.120	-74.315
433.705	0.000097532014582	971.295	969.921	-1.374	2434.097	0.000345136496790	1472.527	1396.500	-76.027
460.001	0.000103145449060	973.934	972.838	-1.096	2458.515	0.000346296478280	1480.969	1403.233	-77.736
482.029	0.000107809414403	976.257	974.457	-1.801	2482.793	0.000347421718729	1489.390	1410.509	-78.881
509.907	0.000113659585965	979.344	976.609	-2.735	2507.442	0.000348536001257	1497.967	1418.106	-79.861
532.777	0.000118413396137	981.998	979.967	-2.031	2535.041	0.000349750619264	1507.604	1425.056	-82.548
558.748	0.000123760905508	985.143	981.933	-3.210	2558.701	0.000350764658315	1515.891	1432.211	-83.680
583.493	0.000128803691937	988.268	985.107	-3.161	2581.986	0.000351738526540	1524.070	1439.055	-85.014
611.554	0.000134458797130	991.962	988.531	-3.431	2607.071	0.000352761432789	1532.906	1445.480	-87.426
634.129	0.000138958081943	995.048	991.086	-3.963	2631.588	0.000353735361238	1541.567	1452.599	-88.968
658.248	0.000143714635315	998.457	994.422	-4.035	2654.653	0.000354628737600	1549.736	1459.835	-89.901
684.072	0.000148748300773	1002.234	997.434	-4.799	2684.768	0.000355762443642	1560.433	1469.199	-91.234
705.124	0.000152805760155	1005.408	1000.876	-4.532	2713.012	0.000356792730417	1570.495	1477.709	-92.786
732.526	0.000158023913982	1009.667	1004.018	-5.648	2733.279	0.000357512772309	1577.734	1482.503	-95.231
752.696	0.000161818862599	1012.892	1007.432	-5.460	2757.260	0.000358344318452	1586.317	1489.196	-97.121
782.323	0.000167321047129	1017.768	1011.254	-6.514	2783.262	0.000359221378831	1595.646	1497.292	-98.355
809.041	0.000172208529710	1022.304	1015.565	-6.739	2810.670	0.000360118733208	1605.504	1504.319	-101.186
837.034	0.000177252713775	1027.196	1019.073	-8.122	2838.309	0.000360996034726	1615.470	1512.353	-103.117
857.170	0.000180832079189	1030.801	1022.852	-7.949	2859.972	0.000361664660259	1623.298	1519.220	-104.078
882.753	0.000185320231561	1035.485	1026.294	-9.191	2887.458	0.000362489382655	1633.250	1526.834	-106.415
908.363	0.000189746166282	1040.288	1031.885	-8.403	2911.043	0.000363176448128	1641.807	1534.916	-106.891
935.422	0.000194348983625	1045.484	1034.363	-11.121	2933.070	0.000363801199084	1649.814	1540.726	-109.088
956.725	0.000197919590860	1049.663	1038.713	-10.949	2956.504	0.000364448277027	1658.347	1548.725	-109.621
986.543	0.000202838418240	1055.638	1044.700	-10.938	2983.778	0.000365178957903	1668.297	1555.046	-113.251
1002.868	0.000205492270865	1058.971	1049.014	-9.957	3006.069	0.000365758528237	1676.443	1562.470	-113.973
1033.179	0.000210346179030	1065.273	1052.495	-12.779	3033.245	0.000366444148964	1686.392	1570.417	-115.976
1061.975	0.000214869207892	1071.396	1058.421	-12.975	3057.374	0.000367033945109	1695.242	1578.054	-117.187
1084.068	0.000218280957401	1076.181	1062.677	-13.504	3082.250	0.000367623637742	1704.379	1585.655	-118.724
1107.805	0.000221890238446	1081.405	1066.960	-14.445	3107.982	0.000368214456497	1713.847	1593.522	-120.325
1133.931	0.000225795522268	1087.253	1071.377	-15.876	3133.483	0.000368781037804	1723.244	1600.080	-123.164
1159.036	0.000229481898722	1092.968	1076.518	-16.450	3158.005	0.000369308478687	1732.293	1608.654	-123.639
1184.402	0.000233140909822	1098.836	1081.816	-17.020	3184.048	0.000369850299977	1741.918	1615.445	-126.474
1206.284	0.000236244807009	1103.972	1087.232	-16.739	3207.868	0.000370329641208	1750.734	1623.756	-126.978
1233.606	0.000240052045308	1110.478	1092.486	-17.993	3234.734	0.000370852041577	1760.690	1630.595	-130.096
1257.536	0.000243324799217	1116.262	1096.881	-19.382	3256.536	0.000371261993000	1768.780	1639.147	-129.633
1281.929	0.000246601946506	1122.238	1102.535	-19.703	3279.827	0.000371686374465	1777.432	1646.444	-130.988
1307.463	0.000249969002123	1128.577	1108.661	-19.917	3308.451	0.000372189093302	1788.079	1654.579	-133.500
1331.536	0.000253084610340	1134.632	1113.833	-20.800	3333.029	0.000372604456135	1797.231	1662.212	-135.019
1356.935	0.000256310615872	1141.102	1119.047	-22.055	3358.978	0.000373027003715	1806.906	1669.892	-137.014
1386.199	0.000259949995496	1148.656	1125.490	-23.166	3381.389	0.000373378938123	1815.269	1674.585	-140.684
1406.463	0.000262422229441	1153.949	1130.003	-23.945	3407.830	0.000373778973760	1825.147	1683.330	-141.818
1432.981	0.000265598539435	1160.950	1136.112	-24.838	3426.021	0.000374044808694	1831.949	1689.103	-142.846
1453.941	0.000268062585625	1166.543	1141.041	-25.502	3458.467	0.000374500298942	1844.093	1699.251	-144.842
1477.524	0.000270786137881	1172.896	1145.902	-26.994	3483.057	0.000374829870800	1853.306	1707.174	-146.131
1504.896	0.000273883460990	1180.351	1152.406	-27.946	3508.829	0.000375161125691	1862.970	1714.270	-148.700
1532.702	0.000276960283930	1188.009	1159.518	-28.491	3533.031	0.000375459244858	1872.054	1721.476	-150.578
1558.966	0.000279803133760	1195.321	1164.752	-30.569	3559.898	0.000375775754714	1882.145	1730.402	-151.743
1584.736	0.000282533500520	1202.567	1170.728	-31.839	3583.016	0.000376036170392	1890.835	1738.836	-151.999
1608.206	0.000284969884836	1209.227	1176.191	-33.035	3606.516	0.000376289780643	1899.675	1744.451	-155.224
1632.059	0.000287397776087	1216.053	1182.031	-34.023	3634.919	0.000376581633489	1910.367	1752.517	-157.851
1658.491	0.000290031782692	1223.684	1188.399	-35.286	3659.735	0.000376823715616	1919.716	1760.693	-159.023
1682.662	0.000292389597147	1230.723	1193.896	-36.827	3684.612	0.000377054534600	1929.093	1767.779	-161.314
1709.332	0.000294935568333	1238.556	1200.831	-37.725	3707.066	0.000377252871586	1937.561	1774.926	-162.635
1731.466	0.000297004757952	1245.107	1206.627	-38.480	3735.376	0.000377489638286	1948.245	1785.556	-162.689
1758.713	0.000299498326498	1253.233	1212.206	-41.027	3758.721	0.000377673923917	1957.060	1792.247	-164.813
1782.727	0.000301647703932	1260.451	1218.930	-41.521	3783.360	0.000377857879773	1966.367	1799.150	-167.217
1809.004	0.000303948749286	1268.408	1224.991	-43.417	3807.424	0.000378027273597	1975.462	1805.479	-169.983
1834.144	0.000306101026897	1276.077	1232.119	-43.958	3834.131	0.000378203600521	1985.560	1814.840	-170.720
1856.165	0.000307947459720	1282.838	1237.956	-44.881	3857.404	0.000378347424010	1994.364	1823.009	-171.355
1883.729	0.000310208447803	1291.357	1244.659	-46.698	3884.155	0.000378501635532	2004.487	1829.612	-174.876
1908.443	0.000312188962001	1299.048	1250.987	-48.061	3909.264	0.000378635764690	2013.993	1837.849	-176.144
1932.226	0.000314053750907	1306.495	1257.720	-48.775	3935.005	0.000378762792904	2023.741	1845.303	-178.438
1956.508	0.000315916921961	1314.144	1264.184	-49.959	3957.499	0.000378865269775	2032.262	1852.544	-179.718
1982.824	0.000317890392404	1322.484	1270.513	-51.971	3984.399	0.000378977557727	2042.455	1860.716	-181.739
2006.097	0.000319596598582	1329.902	1276.609	-53.293					

Table F.3a: Inhomogeneous Isotropic Case: Forward modelling using *a*, and *b* estimates obtained from offset VSP times for segment 2 with receiver at 1974 m.

a = 1293.560359090070		b = 0.972655452341			χ = 0		z = 1973.923		
offset (m)	p	computed time (ms)	observed time (ms)	residual (ms)	offset (m)	p	computed time (ms)	observed time (ms)	residual (ms)
84.530	0.000018982190873	936.349	935.707	-0.642	2011.513	0.000290529231397	1294.968	1269.025	-25.943
93.234	0.000020931809298	936.523	935.612	-0.911	2038.012	0.000291775190130	1302.683	1276.389	-26.295
112.705	0.000025288043555	936.973	936.244	-0.729	2058.654	0.000292711907014	1308.716	1281.452	-27.264
130.648	0.000029294613480	937.463	936.110	-1.353	2089.406	0.000294053457127	1317.738	1291.095	-26.643
152.613	0.000034187440501	938.160	937.377	-0.783	2113.127	0.000295045134147	1324.725	1297.340	-27.385
176.332	0.000039454468919	939.033	938.209	-0.825	2137.010	0.000296006409025	1331.783	1304.095	-27.688
200.664	0.000044836912338	940.059	939.183	-0.876	2162.001	0.000296973075142	1339.193	1308.005	-31.188
222.033	0.000049544397288	941.067	940.566	-0.501	2190.353	0.000298022280650	1347.628	1318.307	-29.321
244.406	0.000054451581743	942.231	941.458	-0.773	2208.538	0.000298669196467	1353.053	1324.103	-28.950
270.447	0.000060132726528	943.723	942.481	-1.241	2240.131	0.000299745693439	1362.506	1332.692	-29.814
293.032	0.000065030972049	945.136	944.033	-1.103	2262.848	0.000300483382502	1369.324	1340.505	-28.819
317.805	0.000070370461679	946.813	945.562	-1.251	2285.069	0.000301176116986	1376.009	1346.629	-29.380
343.415	0.000075850867741	948.686	947.720	-0.966	2313.522	0.000302022353100	1384.590	1354.231	-30.360
369.719	0.000081435171983	950.755	949.464	-1.291	2338.818	0.000302737080698	1392.239	1361.689	-30.550
393.092	0.000086357018149	952.716	952.038	-0.677	2364.031	0.000303415026718	1399.881	1368.898	-30.983
417.457	0.000091445255860	954.882	953.379	-1.503	2387.757	0.000304022273043	1407.087	1376.166	-30.921
443.392	0.000096811251908	957.323	956.346	-0.977	2414.140	0.000304663294570	1415.116	1384.134	-30.982
465.151	0.000101271431056	959.478	958.015	-1.463	2438.493	0.000305223712555	1422.543	1389.482	-33.061
493.184	0.000106959619316	962.397	960.078	-2.319	2462.794	0.000305753646708	1429.967	1396.500	-33.467
515.711	0.000111481011748	964.857	963.346	-1.512	2487.398	0.000306261023094	1437.496	1404.673	-32.823
541.511	0.000116603458744	967.800	965.572	-2.228	2515.010	0.000306796282210	1445.959	1412.021	-33.938
566.218	0.000121450934432	970.741	968.150	-2.591	2538.668	0.000307226832845	1453.223	1420.411	-32.812
594.084	0.000126848297592	974.201	971.846	-2.354	2561.908	0.000307625092185	1460.367	1425.506	-34.862
616.525	0.000131139401836	977.095	974.437	-2.659	2586.946	0.000308027407436	1468.075	1432.678	-35.397
640.390	0.000135647489417	980.279	977.709	-2.570	2611.466	0.000308395086963	1475.632	1439.409	-36.224
666.096	0.000140437668720	983.828	980.848	-2.980	2634.472	0.000308716899894	1482.731	1447.930	-34.801
686.674	0.000144222780769	986.757	983.892	-2.865	2664.740	0.000309106955361	1492.081	1457.009	-35.072
714.131	0.000149202767804	990.785	987.625	-3.160	2693.145	0.000309439411736	1500.866	1465.913	-34.953
734.065	0.000152767296822	993.795	990.735	-3.060	2713.475	0.000309657863337	1507.159	1471.688	-35.472
763.765	0.000157997503982	998.410	994.462	-3.948	2737.504	0.000309895561469	1514.603	1478.316	-36.287
790.341	0.000162594460799	1002.670	998.943	-3.728	2763.498	0.000310128250682	1522.661	1486.156	-36.505
818.537	0.000167384952159	1007.322	1002.359	-4.963	2790.900	0.000310346692380	1531.163	1492.776	-38.386
838.613	0.000170740792904	1010.717	1006.107	-4.610	2818.515	0.000310539656788	1539.736	1501.544	-38.192
864.183	0.000174948191663	1015.136	1009.904	-5.232	2840.130	0.000310672122258	1546.450	1509.010	-37.440
889.644	0.000179062994476	1019.643	1015.459	-4.184	2867.558	0.000310817292801	1554.973	1516.612	-38.361
916.870	0.000183379909046	1024.577	1018.333	-6.244	2891.097	0.000310921916937	1562.290	1522.475	-39.815
938.114	0.000186688343706	1028.508	1022.636	-5.873	2913.083	0.000311003372687	1569.127	1527.969	-41.158
967.871	0.000191234274093	1034.132	1028.093	-6.038	2936.480	0.000311073176291	1576.404	1537.739	-38.665
984.094	0.000193668904164	1037.254	1032.088	-5.166	2963.685	0.000311132972100	1584.868	1544.497	-40.372
1014.404	0.000198135268599	1043.192	1035.925	-7.267	2985.984	0.000311165248682	1591.806	1551.710	-40.096
1043.220	0.000202281936662	1048.961	1041.995	-6.966	3013.154	0.000311184708355	1600.261	1560.112	-40.149
1065.184	0.000205377214812	1053.438	1046.384	-7.054	3037.280	0.000311184131566	1607.769	1566.471	-41.298
1088.895	0.000208655736607	1058.347	1050.471	-7.876	3062.143	0.000311166399951	1615.505	1575.806	-39.700
1115.015	0.000212191529373	1063.843	1055.210	-8.634	3087.867	0.000311130193495	1623.510	1582.710	-40.800
1140.098	0.000215512649352	1069.208	1060.235	-8.973	3113.355	0.000311076852571	1631.439	1587.800	-43.639
1165.295	0.000218775701504	1074.679	1065.256	-9.423	3137.870	0.000311009556220	1639.064	1597.852	-41.212
1187.085	0.000221538853980	1079.476	1070.389	-9.087	3163.910	0.000310921333941	1647.162	1605.218	-41.944
1214.352	0.000224920223129	1085.563	1075.694	-9.870	3187.722	0.000310825938447	1654.564	1614.170	-40.394
1238.248	0.000227814433018	1090.973	1080.502	-10.471	3214.578	0.000310701905449	1662.910	1620.041	-42.869
1262.578	0.000230695110145	1096.551	1085.769	-10.782	3236.351	0.000310588868691	1669.674	1627.195	-42.479
1288.093	0.000233645149634	1102.475	1092.119	-10.356	3259.675	0.000310455687422	1676.917	1634.435	-42.482
1312.260	0.000236372946416	1108.154	1097.591	-10.564	3288.287	0.000310275641559	1685.797	1645.422	-40.375
1337.566	0.000239160734921	1114.171	1102.887	-11.284	3312.831	0.000310106953301	1693.410	1651.273	-42.137
1366.579	0.000242271402339	1121.155	1110.075	-11.080	3338.804	0.000309914496952	1701.462	1660.710	-40.752
1386.806	0.000244386626985	1126.077	1113.877	-12.201	3361.215	0.000309737208976	1708.406	1665.429	-42.977
1413.235	0.000247085070301	1132.572	1120.171	-12.401	3387.640	0.000309515139937	1716.588	1674.863	-41.725
1434.249	0.000249178290980	1137.786	1125.078	-12.709	3405.836	0.000309354230791	1722.218	1681.033	-41.185
1457.820	0.000251471706523	1143.687	1129.865	-13.822	3438.279	0.000309051568774	1732.250	1690.683	-41.567
1485.368	0.000254079766842	1150.651	1136.798	-13.852	3462.882	0.000308808952588	1739.850	1698.660	-41.190
1513.211	0.000256637842761	1157.761	1143.508	-14.253	3488.647	0.000308543104605	1747.803	1706.745	-41.059
1539.303	0.000258964813126	1164.488	1149.417	-15.071	3512.857	0.000308282633396	1755.270	1712.753	-42.517
1565.130	0.000261202296011	1171.205	1154.933	-16.272	3539.715	0.000307981901911	1763.546	1720.417	-43.129
1588.644	0.000263183185992	1177.370	1160.874	-16.496	3562.825	0.000307713483648	1770.660	1742.573	-28.088
1612.475	0.000265136976226	1183.665	1167.062	-16.603	3586.331	0.000307431553123	1777.890	1738.627	-39.263
1638.883	0.000267239695865	1190.695	1173.549	-17.146	3614.704	0.000307079612981	1786.608	1743.987	-42.621
1663.079	0.000269109561008	1197.184	1178.955	-18.229	3639.544	0.000306761325340	1794.232	1750.378	-43.854
1689.771	0.000271110450944	1204.394	1185.425	-18.969	3664.411	0.000306433461998	1801.856	1773.884	-27.972
1711.871	0.000272718776150	1210.403	1191.324	-19.080	3686.858	0.000306129779697	1808.731	1767.780	-40.951
1739.048	0.000274637450703	1217.841	1197.521	-20.321	3715.162	0.000305736705120	1817.390	1773.923	-43.467
1763.081	0.000276280823999	1224.461	1203.817	-20.644	3738.511	0.000305404153905	1824.525	1782.683	-41.842
1789.370	0.000278022009418	1231.747	1210.837	-20.910	3763.146	0.000305045400554	1832.044	1802.645	-29.399
1814.387	0.000279625218169	1238.723	1217.784	-20.939	3787.190	0.000304687642869	1839.375	1796.954	-42.421
1836.461	0.000280996983863	1244.910	1223.474	-21.437	3813.895	0.000304281752525	1847.506	1807.817	-39.689
1863.985	0.000282652328401	1252.668	1231.080	-21.588	3837.164	0.000303920968470	1854.582	1825.078	-29.504
1888.688	0.000284086689463	1259.668	1235.614	-24.054	3863.906	0.000303498367439	1862.704	1823.494	-39.210
1912.386	0.000285418011870	1266.416	1242.405	-24.011	3889.009	0.000303094149029	1870.317	1820.780	-49.538
1936.696	0.000286738971588	1273.371	1250.340	-23.031	3914.736	0.000302672573459	1878.110	1833.245	-44.865
1962.993	0.000288117967948	1280.929	1255.989	-24.941	3937.224	0.000302298177848	1884.912	1860.562	-24.350
1986.236	0.000289294318474	1287.640	1262.363	-25.277	3964.125	0.000301843301095	1893.038	1870.558	-22.480

Table F.3b: Inhomogeneous Isotropic Case: Forward modelling using *a*, and *b* estimates obtained from offset VSP times for segment 2 with receiver at 2014 m.

a = 1293.560359090070		b = 0.972655452341			χ = 0		z = 2013.927		
offset (m)	p	computed time (ms)	observed time (ms)	residual (ms)	offset (m)	p	computed time (ms)	observed time (ms)	residual (ms)
47.917	0.000010464177093	948.171	949.852	1.681	2031.400	0.000286537190995	1305.166033	1283.866	-21.3
67.679	0.000014774907294	948.421	950.437	2.016	2057.867	0.000287770570065	1312.766161	1290.939	-21.83
87.531	0.000019100022460	948.757	950.647	1.890	2078.568	0.000288702303441	1318.732972	1296.333	-22.4
114.917	0.000025055576537	949.362	951.544	2.182	2109.336	0.000290034804078	1327.636639	1305.118	-22.52
136.226	0.000029678525789	949.945	951.374	1.429	2133.030	0.000291019066588	1334.520425	1311.261	-23.26
159.548	0.000034724726342	950.696	953.025	2.329	2156.926	0.000291975607088	1341.486155	1317.697	-23.79
185.804	0.000040385985163	951.682	953.865	2.183	2181.962	0.000292939578749	1348.807974	1322.426	-26.38
210.975	0.000045790819716	952.767	954.950	2.183	2210.257	0.000293983019095	1357.111558	1332.953	-24.16
234.325	0.000050782279183	953.894	956.605	2.711	2228.452	0.000294628700401	1362.466612	1338.401	-24.07
258.040	0.000055827596446	955.158	957.373	2.215	2260.084	0.000295705007115	1371.803415	1346.712	-25.09
284.557	0.000061437365257	956.713	958.386	1.672	2282.716	0.000296439825048	1378.504243	1353.271	-25.23
307.433	0.000066247609643	958.174	960.111	1.937	2304.890	0.000297131846297	1385.085356	1359.676	-25.41
332.872	0.000071562481723	959.927	961.630	1.703	2333.394	0.000297981602401	1393.566938	1367.060	-26.51
359.049	0.000076991158602	961.871	963.944	2.072	2358.739	0.000298700373423	1401.12827	1375.573	-25.56
385.343	0.000082400008864	963.967	965.418	1.451	2383.962	0.000299382080420	1408.671125	1382.318	-26.35
409.334	0.000087294629779	966.002	968.447	2.445	2407.702	0.000299993705062	1415.785889	1389.120	-26.67
433.705	0.000092224811595	968.190	969.921	1.731	2434.097	0.000300640294930	1423.712876	1396.500	-27.21
460.001	0.000097494707894	970.685	972.838	2.153	2458.515	0.000301207761040	1431.060711	1403.233	-27.83
482.029	0.000101868070568	972.880	974.457	1.576	2482.793	0.000301743389345	1438.380001	1410.509	-27.87
509.907	0.000107346628809	975.797	976.609	0.813	2507.442	0.000302258647601	1445.824115	1418.106	-27.72
532.777	0.000111792273278	978.303	979.967	1.664	2535.041	0.000302802182772	1454.173731	1425.056	-29.12
558.748	0.000116786051718	981.271	981.933	0.662	2558.701	0.000303240689692	1461.343342	1432.211	-29.13
583.493	0.000121487973313	984.219	985.107	0.888	2581.986	0.000303648033500	1468.40907	1439.055	-29.35
611.554	0.000126751860891	987.702	988.531	0.829	2607.071	0.000304060567873	1476.031308	1445.480	-30.55
634.129	0.000130932708626	990.611	991.086	0.475	2631.588	0.000304437973542	1483.490671	1452.599	-30.89
658.248	0.000135345292465	993.822	994.422	0.600	2654.653	0.000304770257394	1490.516445	1459.835	-30.68
684.072	0.000140006291512	997.378	997.434	0.057	2684.768	0.000305171643450	1499.700643	1469.199	-30.5
705.124	0.000143756528023	1000.365	1000.876	0.511	2713.012	0.000305515503270	1508.324723	1477.709	-30.62
732.526	0.000148570112923	1004.370	1004.018	-0.352	2733.279	0.000305743276314	1514.519031	1482.503	-32.02
752.696	0.000152063811018	1007.402	1007.432	0.030	2757.260	0.000305992752994	1521.854023	1489.196	-32.66
782.323	0.000157118123098	1011.982	1011.254	-0.728	2783.262	0.000306239248766	1529.813684	1497.292	-32.52
809.041	0.000161596143601	1016.240	1015.565	-0.675	2810.670	0.000306472672865	1538.210337	1504.319	-33.89
837.034	0.000166205575137	1020.829	1019.073	-1.755	2838.309	0.000306681309221	1546.683912	1512.353	-34.33
857.170	0.000169468549131	1024.208	1022.852	-1.356	2859.972	0.000306826502368	1553.329408	1519.220	-34.11
882.753	0.000173550246682	1028.596	1026.294	-2.302	2887.458	0.000306988071186	1561.764953	1526.834	-34.93
908.363	0.000177564231130	1033.092	1031.885	-1.207	2911.043	0.000307106984342	1569.00688	1534.916	-34.09
935.422	0.000181726277618	1037.953	1034.363	-3.590	2933.070	0.000307201956332	1575.772417	1540.726	-35.05
956.725	0.000184945842462	1041.859	1038.713	-3.146	2956.504	0.000307286317245	1582.972457	1548.725	-34.25
986.543	0.000189367338202	1047.440	1044.700	-2.740	2983.778	0.000307363343420	1591.354556	1555.046	-36.31
1002.868	0.000191745952373	1050.551	1049.014	-1.537	3006.069	0.000307409782915	1598.206304	1562.470	-35.74
1033.179	0.000196083266980	1056.429	1052.495	-3.934	3033.245	0.000307446801344	1606.561061	1570.417	-36.14
1061.975	0.000200108802190	1062.134	1058.421	-3.713	3057.374	0.000307462044116	1613.979912	1578.054	-35.93
1084.068	0.000203134445492	1066.588	1062.677	-3.911	3082.250	0.000307460826162	1621.628091	1585.655	-35.97
1107.805	0.000206324613273	1071.448	1066.960	-4.487	3107.982	0.000307441913397	1629.539706	1593.522	-36.02
1133.931	0.000209763489890	1076.883	1071.377	-5.506	3133.483	0.000307405898013	1637.379133	1600.080	-37.3
1159.036	0.000212996672922	1082.190	1076.518	-5.672	3158.005	0.000307355444778	1644.916798	1608.654	-36.26
1184.402	0.000216192813098	1087.634	1081.816	-5.817	3184.048	0.000307285300953	1652.920402	1615.445	-37.48
1206.284	0.000218893395226	1092.394	1087.232	-5.162	3207.868	0.000307206571840	1660.239003	1623.756	-36.48
1233.606	0.000222191907375	1098.420	1092.486	-5.934	3234.734	0.000307101486441	1668.491209	1630.595	-37.9
1257.536	0.000225014420901	1103.771	1096.881	-6.890	3256.536	0.000307003826761	1675.185435	1639.147	-36.04
1281.929	0.000227828155927	1109.294	1102.535	-6.759	3279.827	0.000306887529662	1682.334444	1646.444	-35.89
1307.463	0.000230705362587	1115.148	1108.661	-6.488	3308.451	0.000306728081802	1691.116789	1654.579	-36.54
1331.536	0.000233354722768	1120.734	1113.833	-6.901	3333.029	0.000306577018202	1698.653555	1662.212	-36.44
1356.935	0.000236084177067	1126.696	1119.047	-7.649	3358.978	0.000306403701340	1706.606811	1669.892	-36.72
1386.199	0.000239145694040	1133.650	1125.490	-8.160	3381.389	0.000306242878497	1713.471678	1674.585	-38.89
1406.463	0.000241214177712	1138.517	1130.003	-8.513	3407.830	0.000306040189320	1721.566383	1683.330	-38.24
1432.981	0.000243857795730	1144.948	1136.112	-8.837	3426.021	0.000305892788316	1727.13241	1689.103	-38.03
1453.941	0.000245897324342	1150.081	1141.041	-9.040	3458.467	0.000305614226004	1737.052984	1699.251	-37.8
1477.524	0.000248139665889	1155.907	1145.902	-10.005	3483.057	0.000305390093825	1744.565147	1707.174	-37 39
1504.896	0.000250673745966	1162.734	1152.406	-10.328	3508.829	0.000305143476875	1752.43251	1714.270	-38.16
1532.702	0.000253173357079	1169.739	1159.518	-10.221	3533.031	0.000304901254517	1759.814795	1721.476	-38 34
1558.966	0.000255466397630	1176.418	1164.752	-11.667	3559.898	0.000304620637807	1768.002728	1730.402	-37.6
1584.736	0.000257653040293	1183.030	1170.728	-12.302	3583.016	0.000304369554956	1775.042037	1738.836	-36.21
1608.206	0.000259590660033	1189.100	1176.191	-12.909	3606.516	0.000304105438164	1782.191635	1744.451	-37.74
1632.059	0.000261508190143	1195.315	1182.031	-13.285	3634.919	0.000303774571144	1790.824702	1752.517	-38.31
1658.491	0.000263572749266	1202.255	1188.399	-13.856	3659.735	0.000303475358613	1798.359458	1760.693	-37.67
1682.662	0.000265406257730	1208.648	1193.896	-14.751	3684.612	0.000303166195433	1805.904953	1767.779	-38.13
1709.332	0.000267369870581	1215.753	1200.831	-14.921	3707.066	0.000302879405988	1812.709206	1774.926	-37.78
1731.466	0.000268952785066	1221.688	1206.627	-15.061	3735.376	0.000302507671725	1821.278546	1785.556	-35.72
1758.713	0.000270844141813	1229.042	1212.206	-16.836	3758.721	0.000302192845022	1828.336888	1792.247	-36.09
1782.727	0.000272459556381	1235.565	1218.930	-16.635	3783.360	0.000301852669512	1835.778355	1799.150	-36.63
1809.004	0.000274172943041	1242.748	1224.991	-17.756	3807.424	0.000301512805573	1843.038075	1805.479	-37.56
1834.144	0.000275759844402	1249.660	1232.119	-17.541	3834.131	0.000301127047200	1851.08536	1814.840	-36.25
1856.165	0.000277108574260	1255.748	1237.956	-17.791	3857.404	0.000300783735371	1858.089555	1823.009	-35.08
1883.729	0.000278743423540	1263.409	1244.659	-18.749	3884.155	0.000300381127765	1866.130587	1829.612	-36.52
1908.443	0.000280159655355	1270.315	1250.987	-19.328	3909.264	0.000299995688552	1873.668056	1837.849	-35.82
1932.226	0.000281478976545	1276.994	1257.720	-19.274	3935.005	0.000299593196348	1881.384885	1845.303	-36.08
1956.508	0.000282782800712	1283.845	1264.184	-19.660	3957.499	0.000299235535553	1888.119923	1852.544	-35 58
1982.824	0.000284147419132	1291.305	1270.513	-20.792	3984.399	0.000298800768391	1896.163513	1860.716	-35.45
2006.097	0.000285312991392	1297.931	1276.609	-21.323					

Table F.4a: Inhomogeneous Isotropic Case: Forward modelling using *a*, and *b* estimates obtained from offset VSP times for segment 3 with receiver at 1974 m.

a = 1131.623428157450		b = 1.219952706708			χ = 0		z = 1973.923		
offset (m)	p	computed time (ms)	observed time (ms)	residual (ms)	offset (m)	p	computed time (ms)	observed time (ms)	residual (ms)
84.530	0.000018313250589	935.559	935.707	0.148	2011.513	0.000270528167845	1275.503	1269.025	-6.478
93.234	0.000020193826047	935.727	935.612	-0.115	2038.012	0.000271481523931	1282.685	1276.389	-6.296
112.705	0.000024395417815	936.161	936.244	0.083	2058.654	0.000272191125791	1288.296	1281.452	-6.845
130.648	0.000028259230231	936.633	936.110	-0.523	2089.406	0.000273195755973	1296.682	1291.095	-5.587
152.613	0.000032976912204	937.306	937.377	0.071	2113.127	0.000273928759408	1303.171	1297.340	-5.831
176.332	0.000038054241407	938.148	938.209	0.060	2137.010	0.000274630722561	1309.722	1304.095	-5.627
200.664	0.000043241390854	939.137	939.183	0.045	2162.001	0.000275327329885	1316.594	1308.005	-8.589
222.033	0.000047776716390	940.110	940.566	0.456	2190.353	0.000276071802233	1324.411	1318.307	-6.104
244.406	0.000052502929612	941.232	941.458	0.226	2208.538	0.000276524221343	1329.435	1324.103	-5.333
270.447	0.000057972420960	942.670	942.481	-0.189	2240.131	0.000277264685708	1338.183	1332.692	-5.491
293.032	0.000062686143767	944.033	944.033	0.000	2262.848	0.000277762246698	1344.488	1340.505	-3.983
317.805	0.000067822124266	945.649	945.562	-0.087	2285.069	0.000278221364623	1350.665	1346.629	-4.036
343.415	0.000073090846801	947.454	947.720	0.266	2313.522	0.000278770351021	1358.589	1354.231	-4.359
369.719	0.000078456264101	949.447	949.464	0.017	2338.818	0.000279222639365	1365.647	1361.689	-3.958
393.092	0.000083182291977	951.336	952.038	0.702	2364.031	0.000279640771954	1372.692	1368.898	-3.794
417.457	0.000088065009761	953.423	953.379	-0.044	2387.757	0.000280005174918	1379.331	1376.166	-3.165
443.392	0.000093210615246	955.773	956.346	0.573	2414.140	0.000280378087612	1386.724	1384.134	-2.590
465.151	0.000097484550949	957.848	958.015	0.167	2438.493	0.000280692865186	1393.556	1389.482	-4.073
493.184	0.000102930900570	960.657	960.078	-0.580	2462.794	0.000280979487546	1400.380	1396.500	-3.881
515.711	0.000107256378387	963.025	963.346	0.321	2487.398	0.000281242393517	1407.297	1404.673	-2.624
541.511	0.000112152653870	965.855	965.572	-0.284	2515.010	0.000281505582120	1415.066	1412.021	-3.045
566.218	0.000116781713602	968.684	968.150	-0.534	2538.668	0.000281704972904	1421.728	1420.411	-1.318
594.084	0.000121930529493	972.010	971.846	-0.164	2561.908	0.000281877957231	1428.277	1425.506	-2.772
616.525	0.000126019750225	974.792	974.437	-0.355	2586.946	0.000282039580937	1435.337	1432.678	-2.659
640.390	0.000130311413722	977.851	977.709	-0.142	2611.466	0.000282173604967	1442.254	1439.409	-2.846
666.096	0.000134866478516	981.259	980.848	-0.412	2634.472	0.000282278072496	1448.747	1447.930	-0.817
686.674	0.000138461846155	984.072	983.892	-0.180	2664.740	0.000282384983711	1457.293	1457.009	-0.284
714.131	0.000143186553927	987.938	987.625	-0.314	2693.145	0.000282454659565	1465.315	1465.913	0.598
734.065	0.000146564220369	990.826	990.735	-0.092	2713.475	0.000282486809048	1471.058	1471.688	0.630
763.765	0.000151513618445	995.253	994.462	-0.791	2737.504	0.000282506239161	1477.846	1478.316	0.470
790.341	0.000155856877013	999.338	998.943	-0.395	2763.498	0.000282505176003	1485.189	1486.156	0.967
818.537	0.000160375690842	1003.796	1002.359	-1.437	2790.900	0.000282479896306	1492.930	1492.776	-0.154
838.613	0.000163536528566	1007.048	1006.107	-0.941	2818.515	0.000282430067201	1500.730	1501.544	0.813
864.183	0.000167493683580	1011.280	1009.904	-1.376	2840.130	0.000282374482239	1506.835	1509.010	2.175
889.644	0.000171357225174	1015.594	1015.459	-0.135	2867.558	0.000282283579839	1514.578	1516.612	2.033
916.870	0.000175403197378	1020.315	1018.333	-1.982	2891.097	0.000282187882724	1521.222	1522.475	1.253
938.114	0.000178498618880	1024.074	1022.636	-1.438	2913.083	0.000282084141967	1527.425	1527.969	0.544
967.871	0.000182743825248	1029.449	1028.093	-1.356	2936.480	0.000281958910318	1534.023	1537.739	3.716
984.094	0.000185013384794	1032.432	1032.088	-0.344	2963.685	0.000281794579443	1541.692	1544.497	2.805
1014.404	0.000189169234577	1038.103	1035.925	-2.178	2985.984	0.000281645299694	1547.974	1551.710	3.736
1043.220	0.000193018206931	1043.610	1041.995	-1.615	3013.154	0.000281446158424	1555.624	1560.112	4.488
1065.184	0.000195885011217	1047.881	1046.384	-1.496	3037.280	0.000281253889886	1562.412	1566.471	4.059
1088.895	0.000198915376656	1052.562	1050.471	-2.091	3062.143	0.000281041002300	1569.402	1575.806	6.404
1115.015	0.000202176063752	1057.800	1055.210	-2.590	3087.867	0.000280805440333	1576.628	1582.710	6.081
1140.098	0.000205231321384	1062.910	1060.235	-2.675	3113.355	0.000280557147459	1583.782	1587.800	4.018
1165.295	0.000208225721094	1068.119	1065.256	-2.863	3137.870	0.000280304765334	1590.657	1597.852	7.195
1187.085	0.000210755303094	1072.684	1070.389	-2.295	3163.910	0.000280022550788	1597.953	1605.218	7.265
1214.352	0.000213842840317	1078.472	1075.694	-2.779	3187.722	0.000279752110729	1604.617	1614.170	9.553
1238.248	0.000216478170256	1083.614	1080.502	-3.113	3214.578	0.000279433350857	1612.126	1620.041	7.915
1262.578	0.000219094030991	1088.913	1085.769	-3.144	3236.351	0.000279164544271	1618.207	1627.195	8.988
1288.093	0.000221765073229	1094.538	1092.119	-2.419	3259.675	0.000278866587351	1624.715	1634.435	9.720
1312.260	0.000224227465712	1099.927	1097.591	-2.336	3288.287	0.000278487343331	1632.689	1645.422	12.733
1337.566	0.000226736215123	1105.633	1102.887	-2.746	3312.831	0.000278150368356	1639.520	1651.273	11.754
1366.579	0.000229525653264	1112.252	1110.075	-2.177	3338.804	0.000277782415500	1646.739	1660.710	13.971
1386.806	0.000231416151014	1116.914	1113.877	-3.037	3361.215	0.000277455844963	1652.961	1665.429	12.467
1413.235	0.000233820067900	1123.062	1120.171	-2.891	3387.640	0.000277060293659	1660.288	1674.863	14.575
1434.249	0.000235678444852	1127.995	1125.078	-2.917	3405.836	0.000276781528313	1665.326	1681.033	15.707
1457.820	0.000237707798907	1133.574	1129.865	-3.709	3438.279	0.000276271947868	1674.298	1690.683	16.385
1485.368	0.000240006484581	1140.154	1136.798	-3.356	3462.882	0.000275875169111	1681.090	1698.660	17.570
1513.211	0.000242251117969	1146.868	1143.508	-3.361	3488.647	0.000275450402218	1688.193	1706.745	18.552
1539.303	0.000244283785852	1153.216	1149.417	-3.799	3512.857	0.000275042960464	1694.856	1712.753	17.896
1565.130	0.000246229490202	1159.550	1154.933	-4.617	3539.715	0.000274581840351	1702.237	1720.417	18.179
1588.644	0.000247944410361	1165.360	1160.874	-4.486	3562.825	0.000274177640554	1708.578	1742.573	33.994
1612.475	0.000249628391069	1171.289	1167.062	-4.227	3586.331	0.000273759707480	1715.018	1738.627	23.609
1638.883	0.000251431910177	1177.905	1173.549	-4.357	3614.704	0.000273246427053	1722.778	1743.987	21.209
1663.079	0.000253027524302	1184.008	1178.955	-5.053	3639.544	0.000272789404347	1729.560	1750.378	20.818
1689.771	0.000254725829513	1190.785	1185.425	-5.360	3664.411	0.000272324999423	1736.338	1773.884	37.546
1711.871	0.000256083656358	1196.430	1191.324	-5.106	3686.858	0.000271900065044	1742.446	1767.780	25.334
1739.048	0.000257694423087	1203.411	1197.521	-5.891	3715.162	0.000271356794507	1750.134	1773.923	23.789
1763.081	0.000259065690911	1209.621	1203.817	-5.804	3738.511	0.000270902590490	1756.465	1782.683	26.218
1789.370	0.000260509528327	1216.451	1210.837	-5.613	3763.146	0.000270417677895	1763.132	1802.645	39.513
1814.387	0.000261830130192	1222.984	1217.784	-5.201	3787.190	0.000269938942065	1769.629	1796.954	27.325
1836.461	0.000262952896057	1228.776	1223.474	-5.303	3813.895	0.000269401171165	1776.830	1807.817	30.987
1863.985	0.000264298288764	1236.033	1231.080	-4.953	3837.164	0.000268927595031	1783.093	1825.078	41.985
1888.688	0.000265455070154	1242.576	1235.614	-6.962	3863.906	0.000268377781416	1790.278	1823.494	33.216
1912.386	0.000266520691264	1248.880	1242.405	-6.475	3889.009	0.000267856483907	1797.008	1820.780	23.772
1936.696	0.000267569767600	1255.371	1250.340	-5.032	3914.736	0.000267317254375	1803.892	1833.245	29.352
1962.993	0.000268655477645	1262.422	1255.989	-6.434	3937.224	0.000266841936887	1809.898	1860.562	50.663
1986.236	0.000269573395552	1268.677	1262.363	-6.315	3964.125	0.000266268668101	1817.069	1870.558	53.489

Table F.4b: Inhomogeneous Isotropic Case: Forward modelling using *a*, and *b* estimates obtained from offset VSP times for segment 3 with receiver at 2014 m.

a = 1131.623428157450		b = 1.219952706708			χ = 0		z = 2013.927		
offset (m)	p	computed time (ms)	observed time (ms)	residual (ms)	offset (m)	p	computed time (ms)	observed time (ms)	residual (ms)
47.917	0.000010077824609	946.251	949.852	3.601	2031.400	0.000266416385435	1284.105	1283.866	-0.239
67.679	0.000014229054921	946.491	950.437	3.946	2057.867	0.000267363526428	1291.169	1290.939	-0.230
87.531	0.000018393785357	946.815	950.647	3.833	2078.568	0.000268072222036	1296.711	1296.333	-0.378
114.917	0.000024127724152	947.397	951.544	4.147	2109.336	0.000269074657789	1304.975	1305.118	0.143
136.226	0.000028577872757	947.958	951.374	3.415	2133.030	0.000269805988668	1311.359	1311.261	-0.098
159.548	0.000033434512520	948.682	953.025	4.343	2156.926	0.000270508585433	1317.815	1317.697	-0.118
185.804	0.000038881731216	949.631	953.865	4.234	2181.962	0.000271207796769	1324.596	1322.426	-2.170
210.975	0.000044080645241	950.675	954.950	4.275	2210.257	0.000271953658372	1332.280	1332.953	0.673
234.325	0.000048880373575	951.761	956.605	4.844	2228.452	0.000272408939781	1337.233	1338.401	1.169
258.040	0.000053730183215	952.977	957.373	4.396	2260.084	0.000273156107298	1345.861	1346.712	0.851
284.557	0.000059120328414	954.474	958.386	3.912	2282.716	0.000273656926951	1352.049	1353.271	1.222
307.433	0.000063740175762	955.879	960.111	4.232	2304.890	0.000274120933976	1358.123	1359.676	1.554
332.872	0.000068842230892	957.565	961.630	4.065	2333.394	0.000274679466011	1365.944	1367.060	1.116
359.049	0.000074050641333	959.436	963.944	4.508	2358.739	0.000275141112531	1372.912	1375.573	2.661
385.343	0.000079236861167	961.451	965.418	3.966	2383.962	0.000275568672667	1379.857	1382.318	2.461
409.334	0.000083927064236	963.408	968.447	5.039	2407.702	0.000275942724770	1386.404	1389.120	2.716
433.705	0.000088648286473	965.512	969.921	4.409	2434.097	0.000276327079259	1393.692	1396.500	2.808
460.001	0.000093691180609	967.909	972.838	4.929	2458.515	0.000276653783263	1400.444	1403.233	2.789
482.029	0.000097873101194	970.019	974.457	4.438	2482.793	0.000276951798117	1407.164	1410.509	3.345
509.907	0.000103107646990	972.821	976.609	3.789	2507.442	0.000277227656401	1413.994	1418.106	4.112
532.777	0.000107351634784	975.227	979.967	4.740	2535.041	0.000277505389580	1421.649	1425.056	3.407
558.748	0.000112114731485	978.077	981.933	3.856	2558.701	0.000277717952447	1428.217	1432.211	3.994
583.493	0.000116595176078	980.907	985.107	4.200	2581.986	0.000277904699109	1434.686	1439.055	4.369
611.554	0.000121605870133	984.249	988.531	4.281	2607.071	0.000278081568837	1441.660	1445.480	3.820
634.129	0.000125581426486	987.040	991.086	4.046	2631.588	0.000278230663522	1448.479	1452.599	4.119
658.248	0.000129773072567	990.119	994.422	4.303	2654.653	0.000278350003618	1454.898	1459.835	4.936
684.072	0.000134195663345	993.528	997.434	3.907	2684.768	0.000278476091829	1463.283	1469.199	5.916
705.124	0.000137750115596	996.390	1000.876	4.486	2713.012	0.000278564604367	1471.149	1477.709	6.560
732.526	0.000142306930320	1000.227	1004.018	3.791	2733.279	0.000278610860593	1476.795	1482.503	5.708
752.696	0.000145610210205	1003.131	1007.432	4.301	2757.260	0.000278647434411	1483.477	1489.196	5.719
782.323	0.000150382657366	1007.516	1011.254	3.738	2783.262	0.000278665397393	1490.723	1497.292	6.569
809.041	0.000154604277738	1011.591	1015.565	3.974	2810.670	0.000278660561922	1498.361	1504.319	5.958
837.034	0.000158942824314	1015.979	1019.073	3.094	2838.309	0.000278631688574	1506.062	1512.353	6.291
857.170	0.000162009536929	1019.211	1022.852	3.642	2859.972	0.000278592671319	1512.098	1519.220	7.122
882.753	0.000165840187052	1023.405	1026.294	2.889	2887.458	0.000278523015010	1519.754	1526.834	7.080
908.363	0.000169600969009	1027.700	1031.885	4.185	2911.043	0.000278445743150	1526.323	1534.916	8.593
935.422	0.000173493477275	1032.342	1034.363	2.021	2933.070	0.000278359371603	1532.455	1540.726	8.271
956.725	0.000176499391288	1036.070	1038.713	2.643	2956.504	0.000278252794326	1538.977	1548.725	9.748
986.543	0.000180619740861	1041.395	1044.700	3.305	2983.778	0.000278110196770	1546.564	1555.046	8.482
1002.868	0.000182832464849	1044.362	1049.014	4.652	3006.069	0.000277979234002	1552.762	1562.470	9.709
1033.179	0.000186859902941	1049.965	1052.495	2.530	3033.245	0.000277802516034	1560.314	1570.417	10.103
1061.975	0.000190588838831	1055.399	1058.421	3.021	3057.374	0.000277630338816	1567.015	1578.054	11.039
1084.068	0.000193385515732	1059.641	1062.677	3.036	3082.250	0.000277438240523	1573.919	1585.655	11.736
1107.805	0.000196328349914	1064.267	1066.960	2.694	3107.982	0.000277224360410	1581.055	1593.522	12.467
1133.931	0.000199493452877	1069.437	1071.377	1.940	3133.483	0.000276997646939	1588.122	1600.080	11.958
1159.036	0.000202462094394	1074.483	1076.518	2.035	3158.005	0.000276766168834	1594.911	1608.654	13.743
1184.402	0.000205389537920	1079.656	1081.816	2.160	3184.048	0.000276506307976	1602.116	1615.445	13.329
1206.284	0.000207857220313	1084.177	1087.232	3.055	3207.868	0.000276256345859	1608.699	1623.756	15.057
1233.606	0.000210863579854	1089.898	1092.486	2.588	3234.734	0.000275960752155	1616.117	1630.595	14.477
1257.536	0.000213429026238	1094.975	1096.881	1.906	3256.536	0.000275710546288	1622.131	1639.147	17.016
1281.929	0.000215979634774	1100.212	1102.535	2.323	3279.827	0.000275433307924	1628.549	1646.444	17.895
1307.463	0.000218580307174	1105.760	1108.661	2.901	3308.451	0.000275078924073	1636.428	1654.579	18.151
1331.536	0.000220967978772	1111.051	1113.833	2.782	3333.029	0.000274763004763	1643.185	1662.212	19.026
1356.935	0.000223420360172	1116.695	1119.047	2.352	3358.978	0.000274418151648	1650.311	1669.892	19.581
1386.199	0.000226161529819	1123.273	1125.490	2.217	3381.389	0.000274111267344	1656.457	1674.585	18.128
1406.463	0.000228007519536	1127.875	1130.003	2.129	3407.830	0.000273738723752	1663.700	1683.330	19.629
1432.981	0.000230359254664	1133.952	1136.112	2.159	3426.021	0.000273476014978	1668.677	1689.103	20.426
1453.941	0.000232167524640	1138.800	1141.041	2.241	3458.467	0.000272994927908	1677.543	1699.251	21.708
1477.524	0.000234149165716	1144.298	1145.902	1.604	3483.057	0.000272619980633	1684.251	1707.174	22.923
1504.896	0.000236380040271	1150.738	1152.406	1.667	3508.829	0.000272217758070	1691.272	1714.270	22.998
1532.702	0.000238571081611	1157.342	1159.518	2.177	3533.031	0.000271831694255	1697.856	1721.476	23.620
1558.966	0.000240572219100	1163.634	1164.752	1.118	3559.898	0.000271393986514	1705.153	1730.402	25.249
1584.736	0.000242472115066	1169.858	1170.728	0.870	3583.016	0.000271009900573	1711.423	1738.836	27.414
1608.206	0.000244148374147	1175.569	1176.191	0.623	3606.516	0.000270612630478	1717.787	1744.451	26.665
1632.059	0.000245800118410	1181.412	1182.031	0.618	3634.919	0.000270123569152	1725.466	1752.517	27.050
1658.491	0.000247570083145	1187.933	1188.399	0.466	3659.735	0.000269688591487	1732.164	1760.693	28.528
1682.662	0.000249134171907	1193.936	1193.896	-0.039	3684.612	0.000269245612067	1738.868	1767.779	28.911
1709.332	0.000250800571321	1200.603	1200.831	0.229	3707.066	0.000268839983006	1744.909	1774.926	30.018
1731.466	0.000252136944573	1206.169	1206.627	0.459	3735.376	0.000268321040862	1752.512	1785.556	33.044
1758.713	0.000253725033063	1213.060	1212.206	-0.854	3758.721	0.000267887013630	1758.771	1792.247	33.475
1782.727	0.000255073440362	1219.169	1218.930	-0.239	3783.360	0.000267423164420	1765.366	1799.150	33.784
1809.004	0.000256495014746	1225.891	1224.991	-0.900	3807.424	0.000266964614036	1771.796	1805.479	33.684
1834.144	0.000257803182680	1232.356	1232.119	-0.237	3834.131	0.000266449553069	1778.919	1814.840	35.922
1856.165	0.000258908170164	1238.045	1237.956	-0.089	3857.404	0.000265995623692	1785.114	1823.009	37.894
1883.729	0.000260238533279	1245.200	1244.659	-0.541	3884.155	0.000265468221822	1792.223	1829.612	37.388
1908.443	0.000261382408473	1251.646	1250.987	-0.659	3909.264	0.000264967926627	1798.883	1837.849	38.966
1932.226	0.000262440293120	1257.875	1257.720	-0.155	3935.005	0.000264449962984	1805.696	1845.303	39.606
1956.508	0.000263477898627	1264.260	1264.184	-0.076	3957.499	0.000263993264310	1811.640	1852.544	40.904
1982.824	0.000264554880444	1271.208	1270.513	-0.695	3984.399	0.000263442334426	1818.734	1860.716	41.983
2006.097	0.000265466909901	1277.376	1276.609	-0.767					

Table F.5a: Inhomogeneous Isotropic Case: Forward modelling using *a*, and *b* estimates obtained from offset VSP times for segment 4 with receiver at 1974 m.

a = 1425.439346594540		b = 0.853369860705650			z = 0		z = 1973.923		
offset (m)	p	computed time (ms)	observed time (ms)	residual (ms)	offset (m)	p	computed time (ms)	observed time (ms)	residual (ms)
84.530	0.000018864508023	914.960	935.707	20.747	2011.513	0.000294367466121	1274.747	1269.025	-5.722
93.234	0.000020802219123	915.133	935.612	20.479	2038.012	0.000295759812817	1282.566	1276.389	-6.178
112.705	0.000025132045942	915.580	936.244	20.664	2058.654	0.000296811394128	1288.683	1281.452	-7.231
130.648	0.000029114609078	916.067	936.110	20.043	2089.406	0.000298325331650	1297.833	1291.095	-6.739
152.613	0.000033978550086	916.760	937.377	20.618	2113.127	0.000299450968586	1304.923	1297.340	-7.583
176.332	0.000039215100961	917.628	938.209	20.581	2137.010	0.000300547932548	1312.088	1304.095	-7.993
200.664	0.000044567165685	918.647	939.183	20.535	2162.001	0.000301657398038	1319.613	1308.005	-11.608
222.033	0.000049248804581	919.649	940.566	20.917	2190.353	0.000302869557998	1328.183	1318.307	-9.876
244.406	0.000054129852080	920.806	941.458	20.652	2208.538	0.000303621488930	1333.698	1324.103	-9.595
270.447	0.000059781881043	922.289	942.481	20.192	2240.131	0.000304881274748	1343.310	1332.692	-10.618
293.032	0.000064656112610	923.694	944.033	20.338	2262.848	0.000305751382153	1350.246	1340.505	-9.741
317.805	0.000069970691303	925.362	945.562	20.200	2285.069	0.000306574098918	1357.049	1346.629	-10.421
343.415	0.000075427032321	927.224	947.720	20.496	2313.522	0.000307587372938	1365.787	1354.231	-11.556
369.719	0.000080988528352	929.281	949.464	20.183	2338.818	0.000308451118525	1373.579	1361.689	-11.890
393.092	0.000085891830139	931.232	952.038	20.807	2364.031	0.000309278021622	1381.366	1368.898	-12.468
417.457	0.000090962556139	933.386	953.379	19.992	2387.757	0.000310025788105	1388.713	1376.166	-12.546
443.392	0.000096312054229	935.815	956.346	20.531	2414.140	0.000310823407643	1396.903	1384.134	-12.769
465.151	0.000100760171659	937.959	958.015	20.056	2438.493	0.000311528651305	1404.481	1389.482	-14.999
493.184	0.000106435314073	940.863	960.078	19.215	2462.794	0.000312203320240	1412.060	1396.500	-15.560
515.711	0.000110948334028	943.312	963.346	20.034	2487.398	0.000312857414637	1419.749	1404.673	-15.077
541.511	0.000116063584573	946.240	965.572	19.331	2515.010	0.000313557492972	1428.397	1412.021	-16.376
566.218	0.000120906637628	949.168	968.150	18.982	2538.668	0.000314129362439	1435.823	1420.411	-15.412
594.084	0.000126301998337	952.612	971.846	19.234	2561.908	0.000314666487247	1443.129	1425.506	-17.623
616.525	0.000130593850834	955.495	974.437	18.942	2586.946	0.000315218430762	1451.015	1432.678	-18.337
640.390	0.000135105099198	958.666	977.709	19.043	2611.466	0.000315732621618	1458.750	1439.409	-19.342
666.096	0.000139901465396	962.200	980.848	18.647	2634.472	0.000316191842139	1466.019	1447.930	-18.089
686.674	0.000143693647688	965.118	983.892	18.773	2664.740	0.000316762546899	1475.599	1457.009	-18.589
714.131	0.000148686048953	969.132	987.625	18.492	2693.145	0.000317264345332	1484.604	1465.913	-18.691
734.065	0.000152261755518	972.132	990.735	18.603	2713.475	0.000317603850216	1491.057	1471.688	-19.369
763.765	0.000157512041203	976.732	994.462	17.729	2737.504	0.000317984436441	1498.693	1478.316	-20.377
790.341	0.000162130479224	980.980	998.943	17.962	2763.498	0.000318371440441	1506.964	1486.156	-20.808
818.537	0.000166947431300	985.620	1002.359	16.739	2790.900	0.000318752219733	1515.693	1492.776	-22.917
838.613	0.000170324433154	989.005	1006.107	17.101	2818.515	0.000319108390521	1524.501	1501.544	-22.957
864.183	0.000174561596796	993.415	1009.904	16.489	2840.130	0.000319368299854	1531.401	1509.010	-22.392
889.644	0.000178709184991	997.912	1015.459	17.547	2867.558	0.000319674760786	1540.165	1516.612	-23.553
916.870	0.000183064643530	1002.837	1018.333	15.496	2891.097	0.000319917403190	1547.692	1522.475	-25.218
938.114	0.000186405660243	1006.762	1022.636	15.874	2913.083	0.000320127414863	1554.729	1527.969	-26.760
967.871	0.000191000931004	1012.377	1028.093	15.716	2936.480	0.000320333615615	1562.221	1537.739	-24.482
984.094	0.000193464276457	1015.496	1032.088	16.592	2963.685	0.000320551457522	1570.939	1544.497	-26.442
1014.404	0.000197987723294	1021.429	1035.925	14.496	2985.984	0.000320712801999	1578.089	1551.710	-26.378
1043.220	0.000202192793448	1027.195	1041.995	14.800	3013.154	0.000320888924966	1586.805	1560.112	-26.693
1065.184	0.000205335276053	1031.670	1046.384	14.714	3037.280	0.000321026881937	1594.548	1566.471	-28.077
1088.895	0.000208667360628	1036.579	1050.471	13.892	3062.143	0.000321151319478	1602.531	1575.806	-26.726
1115.015	0.000212265261945	1042.076	1055.210	13.133	3087.867	0.000321261545094	1610.794	1582.710	-28.085
1140.098	0.000215649068515	1047.443	1060.235	12.792	3113.355	0.000321352603638	1618.984	1587.800	-31.184
1165.295	0.000218978064378	1052.919	1065.256	12.337	3137.870	0.000321423523131	1626.863	1597.852	-29.011
1187.085	0.000221800626402	1057.721	1070.389	12.668	3163.910	0.000321481369877	1635.233	1605.218	-30.015
1214.352	0.000225259415539	1063.816	1075.694	11.877	3187.722	0.000321518856570	1642.889	1614.170	-28.719
1238.248	0.000228224259109	1069.235	1080.502	11.267	3214.578	0.000321543880228	1651.524	1620.041	-31.483
1262.578	0.000231179485460	1074.824	1085.769	10.945	3236.351	0.000321551036529	1658.525	1627.195	-31.330
1288.093	0.000234210523551	1080.761	1092.119	11.358	3259.675	0.000321545944645	1666.025	1634.435	-31.590
1312.260	0.000237017662435	1086.455	1097.591	11.136	3288.287	0.000321522079352	1675.225	1645.422	-29.803
1337.566	0.000239891225098	1092.490	1102.887	10.397	3312.831	0.000321486502198	1683.116	1651.273	-31.842
1366.579	0.000243103559810	1099.496	1110.075	10.579	3338.804	0.000321434029395	1691.465	1660.710	-30.755
1386.806	0.000245291731563	1104.436	1113.877	9.441	3361.215	0.000321376780091	1698.668	1665.429	-33.240
1413.235	0.000248088004012	1110.956	1120.171	9.215	3387.640	0.000321295353152	1707.160	1674.863	-32.297
1434.249	0.000250261005826	1116.192	1125.078	8.886	3405.836	0.000321230709278	1713.005	1681.033	-31.972
1457.820	0.000252645975689	1122.119	1129.865	7.746	3438.279	0.000321098507711	1723.425	1690.683	-32.742
1485.368	0.000255363743269	1129.116	1136.798	7.682	3462.882	0.000320984126603	1731.323	1698.660	-32.663
1513.211	0.000258035603954	1136.264	1143.508	7.244	3488.647	0.000320851610349	1739.592	1706.745	-32.847
1539.303	0.000260471778100	1143.029	1149.417	6.388	3512.857	0.000320715507601	1747.358	1712.753	-34.605
1565.130	0.000262819749679	1149.786	1154.933	5.147	3539.715	0.000320551699740	1755.970	1720.417	-35.553
1588.644	0.000264903249846	1155.991	1160.874	4.883	3562.825	0.000320400207928	1763.376	1742.573	-20.803
1612.475	0.000266962948661	1162.328	1167.062	4.734	3586.331	0.000320236351556	1770.905	1738.627	-32.278
1638.883	0.000269185220931	1169.408	1173.549	4.141	3614.704	0.000320025766296	1779.988	1743.987	-36.001
1663.079	0.000271166587140	1175.945	1178.955	3.010	3639.544	0.000319830179842	1787.935	1750.378	-37.558
1689.771	0.000273292594416	1183.211	1185.425	2.213	3664.411	0.000319624153968	1795.886	1773.884	-22.002
1711.871	0.000275006141653	1189.270	1191.324	2.053	3686.858	0.000319429590914	1803.058	1767.780	-35.279
1739.048	0.000277056164127	1196.772	1197.521	0.748	3715.162	0.000319172932209	1812.096	1773.923	-38.173
1763.081	0.000278817436293	1203.452	1203.817	0.365	3738.511	0.000318951921395	1819.546	1782.683	-36.863
1789.370	0.000280689390546	1210.806	1210.837	0.031	3763.146	0.000318709868671	1827.400	1802.645	-24.755
1814.387	0.000282418735349	1217.850	1217.784	-0.067	3787.190	0.000318465037451	1835.060	1796.954	-38.106
1836.461	0.000283903116301	1224.101	1223.474	-0.627	3813.895	0.000318183429494	1843.561	1807.817	-35.744
1863.985	0.000285700560083	1231.940	1231.080	-0.860	3837.164	0.000317929951939	1850.962	1825.078	-25.884
1888.688	0.000287263967866	1239.017	1235.614	-3.403	3863.906	0.000317629542002	1859.460	1823.494	-35.966
1912.386	0.000288720384618	1245.842	1242.405	-3.437	3889.009	0.000317338916542	1867.430	1820.780	-46.650
1936.696	0.000290170927089	1252.878	1250.340	-2.539	3914.736	0.000317032634013	1875.590	1833.245	-42.346
1962.993	0.000291691484199	1260.529	1255.989	-4.541	3937.224	0.000316758084419	1882.717	1860.562	-22.155
1986.236	0.000292994091872	1267.324	1262.363	-4.962	3964.125	0.000316421502086	1891.233	1870.558	-20.675

Table F.5b: Inhomogeneous Isotropic Case: Forward modelling using *a*, and *b* estimates obtained from offset VSP times for segment 4 with receiver at 2014 m.

a = 1425.439346594540		b = 0.853369860706			χ = 0		z = 2013.927		
offset (m)	p	computed time (ms)	observed time (ms)	residual (ms)	offset (m)	p	computed time (ms)	observed time (ms)	residual (ms)
47.917	0.000010410433917	927.205	949.852	22.647	2031.400	0.000290613328763	1285.738	1283.866	-1.872
67.679	0.000014699207540	927.453	950.437	22.984	2057.867	0.000291990415347	1293.448	1290.939	-2.509
87.531	0.000019002481816	927.788	950.647	22.859	2078.568	0.000293035323724	1299.503	1296.333	-3.170
114.917	0.000024928374583	928.389	951.544	23.154	2109.336	0.000294537226947	1308.542	1305.118	-3.425
136.226	0.000029528714363	928.970	951.374	22.404	2133.030	0.000295652851243	1315.535	1311.261	-4.274
159.548	0.000034550739504	929.717	953.025	23.308	2156.926	0.000296742627665	1322.613	1317.697	-4.916
185.804	0.000040185614222	930.698	953.865	23.167	2181.962	0.000297846948076	1330.055	1322.426	-7.630
210.975	0.000045566105947	931.777	954.950	23.173	2210.257	0.000299049885862	1338.500	1332.953	-5.547
234.325	0.000050535923015	932.899	956.605	23.705	2228.452	0.000299798591567	1343.948	1338.401	-5.547
258.040	0.000055560283222	934.158	957.373	23.215	2260.084	0.000301054787022	1353.452	1346.712	-6.739
284.557	0.000061147958592	935.705	958.386	22.681	2282.716	0.000301918879419	1360.275	1353.271	-7.004
307.433	0.000065940377086	937.159	960.111	22.952	2304.890	0.000302737978647	1366.979	1359.676	-7.303
332.872	0.000071236873466	938.904	961.630	22.726	2333.394	0.000303751638532	1375.623	1367.060	-8.563
359.049	0.000076648344440	940.839	963.944	23.104	2358.739	0.000304616616821	1383.332	1375.573	-7.759
385.343	0.000082041766424	942.926	965.418	22.492	2383.962	0.000305444222095	1391.026	1382.318	-8.708
409.334	0.000086924026567	944.953	968.447	23.495	2407.702	0.000306193480773	1398.286	1389.120	-9.167
433.705	0.000091843417036	947.131	969.921	22.790	2434.097	0.000306993403767	1406.379	1396.500	-9.879
460.001	0.000097103759853	949.615	972.838	23.223	2458.515	0.000307702959098	1413.884	1403.233	-10.651
482.029	0.000101470859992	951.803	974.457	22.654	2482.793	0.000308380058144	1421.362	1410.509	-10.853
509.907	0.000106943859793	954.708	976.609	21.902	2507.442	0.000309039105363	1428.972	1418.106	-10.866
532.777	0.000111386988901	957.204	979.967	22.762	2535.041	0.000309743774462	1437.511	1425.056	-12.455
558.748	0.000116380221290	960.162	981.933	21.771	2558.701	0.000310320494083	1444.846	1432.211	-12.635
583.493	0.000121083976409	963.100	985.107	22.006	2581.986	0.000310863890483	1452.078	1439.055	-13.023
611.554	0.000126352802555	966.572	988.531	21.959	2607.071	0.000311422994028	1459.884	1445.480	-14.404
634.129	0.000130539884165	969.472	991.086	21.613	2631.588	0.000311943613072	1467.525	1452.599	-14.926
658.248	0.000134961405799	972.674	994.422	21.748	2654.653	0.000312410562416	1474.726	1459.835	-14.891
684.072	0.000139634633405	976.220	997.434	21.215	2684.768	0.000312987626710	1484.143	1469.199	-14.944
705.124	0.000143396908364	979.199	1000.876	21.677	2713.012	0.000313496047300	1492.990	1477.709	-15.280
732.526	0.000148228991585	983.195	1004.018	20.824	2733.279	0.000313841757411	1499.347	1482.503	-16.844
752.696	0.000151738378121	986.220	1007.432	21.212	2757.260	0.000314230590008	1506.878	1489.196	-17.681
782.323	0.000156818960965	990.791	1011.254	20.463	2783.262	0.000314627921255	1515.054	1497.292	-17.762
809.041	0.000161324001542	995.041	1015.565	20.524	2810.670	0.000315019997955	1523.682	1504.319	-19.364
837.034	0.000165965164487	999.622	1019.073	19.451	2838.309	0.000315388230155	1532.394	1512.353	-20.041
857.170	0.000169253144013	1002.997	1022.852	19.855	2859.972	0.000315658211853	1539.230	1519.220	-20.010
882.753	0.000173369259218	1007.380	1026.294	18.914	2887.458	0.000315977684310	1547.910	1526.834	-21.076
908.363	0.000177420679461	1011.872	1031.885	20.013	2911.043	0.000316231695260	1555.366	1534.916	-20.450
935.422	0.000181625528743	1016.730	1034.363	17.633	2933.070	0.000316452477058	1562.334	1540.726	-21.608
956.725	0.000184881146646	1020.634	1038.713	18.079	2956.504	0.000316670287806	1569.752	1548.725	-21.027
986.543	0.000189356590958	1026.214	1044.700	18.486	2983.778	0.000316902082238	1578.392	1555.046	-23.346
1002.868	0.000191766461690	1029.325	1049.014	19.689	3006.069	0.000317074546371	1585.458	1562.470	-22.988
1033.179	0.000196165032363	1035.204	1052.495	17.290	3033.245	0.000317264622841	1594.078	1570.417	-23.661
1061.975	0.000200252631858	1040.912	1058.421	17.509	3057.374	0.000317415198577	1601.735	1578.054	-23.681
1084.068	0.000203328434228	1045.370	1062.677	17.307	3082.250	0.000317552910338	1609.632	1585.655	-23.978
1107.805	0.000206574940604	1050.235	1066.960	16.725	3107.982	0.000317677069635	1617.806	1593.522	-24.284
1133.931	0.000210078738453	1055.678	1071.377	15.699	3133.483	0.000317782159691	1625.908	1600.080	-25.828
1159.036	0.000213377156784	1060.994	1076.518	15.524	3158.005	0.000317866744933	1633.702	1608.654	-25.047
1184.402	0.000216642023032	1066.448	1081.816	15.368	3184.048	0.000317939289558	1641.981	1615.445	-26.536
1206.284	0.000219404146349	1071.219	1087.232	16.013	3207.868	0.000317990394667	1649.555	1623.756	-25.799
1233.606	0.000222782392374	1077.260	1092.486	15.226	3234.734	0.000318030955035	1658.099	1630.595	-27.504
1257.536	0.000225677352089	1082.626	1096.881	14.255	3256.536	0.000318050848241	1665.032	1639.147	-25.886
1281.929	0.000228567413861	1088.166	1102.535	14.369	3279.827	0.000318059490621	1672.440	1646.444	-25.996
1307.463	0.000231527159111	1094.040	1108.661	14.621	3308.451	0.000318052664863	1681.544	1654.579	-26.965
1331.536	0.000234256776185	1099.647	1113.833	14.186	3333.029	0.000318031806284	1689.361	1662.212	-27.149
1356.935	0.000237073439240	1105.633	1119.047	13.414	3358.978	0.000317995104325	1697.613	1669.892	-27.722
1386.199	0.000240238591791	1112.617	1125.490	12.873	3381.389	0.000317951542664	1704.739	1674.585	-30.154
1406.463	0.000242380792143	1117.507	1130.003	12.497	3407.830	0.000317886327002	1713.146	1683.330	-29.816
1432.981	0.000245123236407	1123.970	1136.112	12.141	3426.021	0.000317832949185	1718.928	1689.103	-29.825
1453.941	0.000247242745090	1129.131	1141.041	11.910	3458.467	0.000317720933097	1729.239	1699.251	-29.988
1477.524	0.000249577000300	1134.989	1145.902	10.913	3483.057	0.000317622020893	1737.050	1707.174	-29.876
1504.896	0.000252220275780	1141.857	1152.406	10.549	3508.829	0.000317505707558	1745.234	1714.270	-30.964
1532.702	0.000254833504431	1148.906	1159.518	10.612	3533.031	0.000317384966676	1752.917	1721.476	-31.442
1558.966	0.000257236297107	1155.631	1164.752	9.121	3559.898	0.000317238186399	1761.442	1730.402	-31.040
1584.736	0.000259532867323	1162.290	1170.728	8.439	3583.016	0.000317101398091	1768.775	1738.836	-29.938
1608.206	0.000261572479949	1168.405	1176.191	7.786	3606.516	0.000316952633390	1776.225	1744.451	-31.774
1632.059	0.000263595462591	1174.669	1182.031	7.362	3634.919	0.000316760058398	1785.225	1752.517	-32.708
1658.491	0.000265778917611	1181.665	1188.399	6.734	3659.735	0.000316580646520	1793.083	1760.693	-32.391
1682.662	0.000267722990011	1188.113	1193.896	5.784	3684.612	0.000316390608430	1800.956	1767.779	-33.178
1709.332	0.000269810572026	1195.281	1200.831	5.550	3707.066	0.000316210509415	1808.059	1774.926	-33.132
1731.466	0.000271497892387	1201.272	1206.627	5.356	3735.376	0.000315972145936	1817.007	1785.556	-31.451
1758.713	0.000273519610267	1208.697	1212.206	3.510	3758.721	0.000315766332721	1824.381	1792.247	-32.135
1782.727	0.000275251544455	1215.286	1218.930	3.645	3783.360	0.000315540259418	1832.159	1799.150	-33.008
1809.004	0.000277094124376	1222.543	1224.991	2.448	3807.424	0.000315310885777	1839.749	1805.479	-34.270
1834.144	0.000278806213907	1229.531	1232.119	2.588	3834.131	0.000315046645224	1848.166	1814.840	-33.326
1856.165	0.000280265833019	1235.687	1237.956	2.270	3857.404	0.000314808274063	1855.496	1823.009	-32.487
1883.729	0.000282041047709	1243.436	1244.659	1.223	3884.155	0.000314525187666	1863.914	1829.612	-34.302
1908.443	0.000283584552655	1250.426	1250.987	0.561	3909.264	0.000314250853362	1871.808	1837.849	-33.959
1932.226	0.000285027559750	1257.188	1257.720	0.533	3935.005	0.000313961170719	1879.893	1845.303	-34.590
1956.508	0.000286458848146	1264.126	1264.184	0.058	3957.499	0.000313701186384	1886.952	1852.544	-34.408
1982.824	0.000287962894571	1271.685	1270.513	-1.172	3984.399	0.000313382114966	1895.386	1860.716	-34.670
2006.097	0.000289252832486	1278.401	1276.609	-1.793					

Table F.6a: Inhomogeneous Anisotropic Case: Forward modelling using a, b and χ estimates obtained from offset VSP times for segment 1 with receiver at 1974 m.

a = 1684.101561548270		b = 0.466527250379			χ = 0.052892411471		z = 1973.923		
offset (m)	p	computed time (ms)	observed time (ms)	residual (ms)	offset (m)	p	computed time (ms)	observed time (ms)	residual (ms)
84.530	0.000018042557228	935.749	935.707	-0.042	2011.513	0.000302122566926	1292.655	1269.025	-23.630
93.234	0.000019896596324	935.915	935.612	-0.302	2038.012	0.000303988352806	1300.686	1276.389	-24.297
112.705	0.000024040291855	936.342	936.244	-0.098	2058.654	0.000305412175872	1306.975	1281.452	-25.524
130.648	0.000027852832880	936.808	936.110	-0.698	2089.406	0.000307486016395	1316.399	1291.095	-25.305
152.613	0.000032510933807	937.471	937.377	-0.094	2113.127	0.000309047783220	1323.712	1297.340	-26.372
176.332	0.000037528464206	938.302	938.209	-0.093	2137.010	0.000310587437044	1331.111	1304.095	-27.016
200.664	0.000042659883281	939.277	939.183	-0.095	2162.001	0.000312163809163	1338.893	1308.005	-30.888
222.033	0.000047151532857	940.237	940.566	0.330	2190.353	0.000313910066289	1347.768	1318.307	-29.461
244.406	0.000051837851093	941.344	941.458	0.114	2208.538	0.000315006929916	1353.487	1324.103	-29.384
270.447	0.000057269137741	942.765	942.481	-0.283	2240.131	0.000316870148345	1363.468	1332.692	-30.776
293.032	0.000061957511319	944.111	944.033	-0.078	2262.848	0.000318177334382	1370.682	1340.505	-30.177
317.805	0.000067074661067	945.710	945.562	-0.148	2285.069	0.000319430020627	1377.766	1346.629	-31.137
343.415	0.000072334480667	947.495	947.720	0.225	2313.522	0.000320997217534	1386.877	1354.231	-32.646
369.719	0.000077702673340	949.468	949.464	-0.004	2338.818	0.000322356458898	1395.014	1361.689	-33.325
393.092	0.000082441892707	951.340	952.038	0.698	2364.031	0.000323679931858	1403.158	1368.898	-34.261
417.457	0.000087349659797	953.408	953.379	-0.030	2387.757	0.000324897333905	1410.853	1376.166	-34.686
443.392	0.000092535185017	955.741	956.346	0.605	2414.140	0.000326219711977	1419.442	1384.134	-35.308
465.151	0.000096853586993	957.801	958.015	0.214	2438.493	0.000327411593448	1427.401	1389.482	-37.919
493.184	0.000102372562189	960.594	960.078	-0.516	2462.794	0.000328573895356	1435.371	1396.500	-38.872
515.711	0.000106769327292	962.950	963.346	0.396	2487.398	0.000329723657779	1443.470	1404.673	-38.797
541.511	0.000111761849999	965.769	965.572	-0.197	2515.010	0.000330982215803	1452.591	1412.021	-40.570
566.218	0.000116498082625	968.589	968.150	-0.439	2538.668	0.000332034362597	1460.435	1420.411	-40.024
594.084	0.000121785846091	971.909	971.846	-0.063	2561.908	0.000333044737206	1468.163	1425.506	-42.657
616.525	0.000126001188022	974.689	974.437	-0.253	2586.946	0.000334108093086	1476.515	1432.678	-43.837
640.390	0.000130441172486	977.750	977.709	-0.041	2611.466	0.000335124564631	1484.720	1439.409	-45.311
666.096	0.000135172613304	981.163	980.848	-0.316	2634.472	0.000336056252287	1492.440	1447.930	-44.510
686.674	0.000138921776724	983.984	983.892	-0.092	2664.740	0.000337250210684	1502.630	1457.009	-45.621
714.131	0.000143869330328	987.866	987.625	-0.241	2693.145	0.000338338471993	1512.226	1465.913	-46.313
734.065	0.000147421545179	990.769	990.735	-0.035	2713.475	0.000339098553581	1519.112	1471.688	-47.424
763.765	0.000152651095384	995.226	994.462	-0.764	2737.504	0.000339977052701	1527.270	1478.316	-48.954
790.341	0.000157265541020	999.344	998.943	-0.402	2763.498	0.000340903618065	1536.120	1486.156	-49.964
818.537	0.000162093364603	1003.847	1002.359	-1.488	2790.900	0.000341854108338	1545.474	1492.776	-52.698
838.613	0.000165487609873	1007.135	1006.107	-1.028	2818.515	0.000342785258433	1554.927	1501.544	-53.384
864.183	0.000169758189694	1011.421	1009.904	-1.517	2840.130	0.000343495736753	1562.345	1509.010	-53.335
889.644	0.000173951796213	1015.797	1015.459	-0.338	2867.558	0.000344374461649	1571.778	1516.612	-55.166
916.870	0.000178370500921	1020.593	1018.333	-2.260	2891.097	0.000345108639046	1579.893	1522.475	-57.418
938.114	0.000181770908673	1024.419	1022.636	-1.783	2913.083	0.000345778046629	1587.488	1527.969	-59.519
967.871	0.000186464103375	1029.898	1028.093	-1.804	2936.480	0.000346473341861	1595.586	1537.739	-57.847
984.094	0.000188988032494	1032.943	1032.088	-0.855	2963.685	0.000347260113459	1605.023	1544.497	-60.526
1014.404	0.000193638189971	1038.742	1035.925	-2.817	2985.984	0.000347887866741	1612.773	1551.710	-61.063
1043.220	0.000197979919863	1044.385	1041.995	-2.390	3013.154	0.000348632334556	1622.236	1560.112	-62.124
1065.184	0.000201237050375	1048.769	1046.384	-2.385	3037.280	0.000349274933009	1630.654	1566.471	-64.184
1088.895	0.000204702990142	1053.582	1050.471	-3.111	3062.143	0.000349919316702	1639.347	1575.806	-63.541
1115.015	0.000208460322180	1058.978	1055.210	-3.768	3087.867	0.000350567309827	1648.356	1582.710	-65.647
1140.098	0.000212008910780	1064.251	1060.235	-4.016	3113.355	0.000351190937135	1657.300	1587.800	-69.499
1165.295	0.000215514792524	1069.637	1065.256	-4.381	3137.870	0.000351773773207	1665.916	1597.852	-68.064
1187.085	0.000218499380587	1074.366	1070.389	-3.977	3163.910	0.000352374963244	1675.084	1605.218	-69.866
1214.352	0.000222172572710	1080.374	1075.694	-4.681	3187.722	0.000352908875689	1683.481	1614.170	-69.311
1238.248	0.000225335808119	1085.721	1080.502	-5.220	3214.578	0.000353493224223	1692.967	1620.041	-72.926
1262.578	0.000228502915285	1091.242	1085.769	-5.473	3236.351	0.000353953342068	1700.669	1627.195	-73.474
1288.093	0.000231766693440	1097.114	1092.119	-4.996	3259.675	0.000354432921761	1708.930	1634.435	-74.495
1312.260	0.000234804048294	1102.752	1097.591	-5.162	3288.287	0.000355002804428	1719.079	1645.422	-73.657
1337.566	0.000237928674421	1108.734	1102.887	-5.847	3312.831	0.000355475740782	1727.798	1651.273	-76.525
1366.579	0.000241441168496	1115.688	1110.075	-5.613	3338.804	0.000355960542793	1737.037	1660.710	-76.327
1386.806	0.000243846232284	1120.596	1113.877	-6.719	3361.215	0.000356366108024	1745.019	1665.429	-79.591
1413.235	0.000246935154253	1127.081	1120.171	-6.911	3387.640	0.000356829442781	1754.442	1674.863	-79.580
1434.249	0.000249348175685	1132.296	1125.078	-7.218	3405.836	0.000357139263742	1760.938	1681.033	-79.905
1457.820	0.000252009940546	1138.205	1129.865	-8.340	3438.279	0.000357673386532	1772.534	1690.683	-81.851
1485.368	0.000255061108636	1145.189	1136.798	-8.391	3462.882	0.000358063067317	1781.338	1698.660	-82.678
1513.211	0.000258080545462	1152.333	1143.508	-8.826	3488.647	0.000358457254125	1790.569	1706.745	-83.824
1539.303	0.000260851839714	1159.103	1149.417	-9.687	3512.857	0.000358814895877	1799.251	1712.753	-86.499
1565.130	0.000263540263782	1165.875	1154.933	-10.942	3539.715	0.000359197473250	1808.893	1720.417	-88.477
1588.644	0.000265941086256	1172.100	1160.874	-11.226	3562.825	0.000359514940642	1817.198	1742.573	-74.626
1612.475	0.000268329375450	1178.466	1167.062	-11.404	3586.331	0.000359826912207	1825.653	1738.627	-87.026
1638.883	0.000270923777157	1185.587	1173.549	-12.038	3614.704	0.000360189035723	1835.867	1743.987	-91.880
1663.079	0.000273253284095	1192.171	1178.955	-13.216	3639.544	0.000360493348839	1844.818	1750.378	-94.440
1689.771	0.000275771096374	1199.498	1185.425	-14.073	3664.411	0.000360786308568	1853.786	1773.884	-79.902
1711.871	0.000277815032250	1205.615	1191.324	-14.292	3686.858	0.000361040895192	1861.888	1767.780	-94.108
1739.048	0.000280278547972	1213.199	1197.521	-15.678	3715.162	0.000361348804088	1872.111	1773.923	-98.188
1763.081	0.000282411937565	1219.961	1203.817	-16.144	3738.511	0.000361591996715	1880.551	1782.683	-97.868
1789.370	0.000284697644815	1227.415	1210.837	-16.578	3763.146	0.000361838170647	1889.462	1802.645	-86.816
1814.387	0.000286827054186	1234.564	1217.784	-16.781	3787.190	0.000362068311684	1898.165	1796.954	-101.211
1836.461	0.000288669391959	1240.916	1223.474	-17.442	3813.895	0.000362312388589	1907.837	1807.817	-100.020
1863.985	0.000290919521750	1248.892	1231.080	-17.813	3837.164	0.000362515335055	1916.270	1825.078	-91.192
1888.688	0.000292894986200	1256.103	1235.614	-20.489	3863.906	0.000362737598445	1925.967	1823.494	-102.473
1912.386	0.000294751684592	1263.067	1242.405	-20.662	3889.009	0.000362935739947	1935.076	1820.780	-114.296
1936.696	0.000296617732577	1270.255	1250.340	-19.915	3914.736	0.000363128438467	1944.415	1833.245	-111.171
1962.993	0.000298593190270	1278.081	1255.989	-22.092	3937.224	0.000363288430520	1952.583	1860.562	-92.021
1986.236	0.000300302381763	1285.041	1262.363	-22.679	3964.125	0.000363469648914	1962.358	1870.558	-91.800

Table F.6b: Inhomogeneous Anisotropic Case: Forward modelling using a, b and χ estimates obtained from offset VSP times for segment 1 with receiver at 2014 m.

a = 1684.101561548270		b = 0.466527250379			χ = 0.052892411471		z = 2013.927		
offset (m)	p	computed time (ms)	observed time (ms)	residual (ms)	offset (m)	p	computed time (ms)	observed time (ms)	residual (ms)
47.917	0.000009987115378	950.528	949.852	-0.676	2031.400	0.000299155084195	1307.248	1283.866	-23.382
67.679	0.000014102265159	950.766	950.437	-0.329	2057.867	0.000301000628370	1315.190	1290.939	-24.252
87.531	0.000018232123306	951.087	950.647	-0.440	2078.568	0.000302415244764	1321.436	1296.333	-25.104
114.917	0.000023920945849	951.664	951.544	-0.121	2109.336	0.000304471818840	1330.773	1305.118	-25.655
136.226	0.000028338986548	952.221	951.374	-0.847	2133.030	0.000306018620539	1338.005	1311.261	-26.745
159.548	0.000033164114796	952.938	953.025	0.087	2156.926	0.000307546678503	1345.336	1317.697	-27.640
185.804	0.000038581151975	953.880	953.865	-0.015	2181.962	0.000309113722159	1353.055	1322.426	-30.630
210.975	0.000043757172805	954.916	954.950	0.034	2210.257	0.000310843826788	1361.826	1332.953	-28.873
234.325	0.000048541617826	955.994	956.605	0.611	2228.452	0.000311933794535	1367.492	1338.401	-29.091
258.040	0.000053382387883	957.203	957.373	0.170	2260.084	0.000313787285299	1377.389	1346.712	-30.676
284.557	0.000058770892855	958.690	958.386	-0.304	2282.716	0.000315081747853	1384.505	1353.271	-31.234
307.433	0.000063397105431	960.087	960.111	0.023	2304.890	0.000316324840709	1391.506	1359.676	-31.829
332.872	0.000068515344614	961.765	961.630	-0.135	2333.394	0.000317886752625	1400.545	1367.060	-33.485
359.049	0.000073751094947	963.627	963.944	0.316	2358.739	0.000319242130732	1408.618	1375.573	-33.046
385.343	0.000078976380048	965.635	965.418	-0.218	2383.962	0.000320560382544	1416.687	1382.318	-34.369
409.334	0.000083712942267	967.587	968.447	0.861	2407.702	0.000321773690399	1424.312	1389.120	-35.193
433.705	0.000088492238257	969.685	969.921	0.236	2434.097	0.000323091984065	1432.823	1396.500	-36.323
460.001	0.000093610754498	972.080	972.838	0.758	2458.515	0.000324283229610	1440.726	1403.233	-37.494
482.029	0.000097866785684	974.189	974.457	0.268	2482.793	0.000325441218546	1448.614	1410.509	-38.104
509.907	0.000103209706239	976.992	976.609	-0.382	2507.442	0.000326590385994	1456.650	1418.106	-38.544
532.777	0.000107555146865	979.402	979.967	0.565	2535.041	0.000327845946936	1465.681	1425.056	-40.625
558.748	0.000112447587648	982.259	981.933	-0.326	2558.701	0.000328896610931	1473.450	1432.211	-41.239
583.493	0.000117065605228	985.098	985.107	0.008	2581.986	0.000329907847506	1481.120	1439.055	-42.065
611.554	0.000122249649832	988.456	988.531	0.075	2607.071	0.000330972428866	1489.409	1445.480	-43.929
634.129	0.000126378319396	991.263	991.086	-0.177	2631.588	0.000331988459069	1497.536	1452.599	-44.937
658.248	0.000130747250376	994.364	994.422	0.059	2654.653	0.000332922635805	1505.204	1459.835	-45.370
684.072	0.000135375578838	997.800	997.434	-0.365	2684.768	0.000334111284850	1515.248	1469.199	-46.050
705.124	0.000139110089498	1000.689	1000.876	0.187	2713.012	0.000335194752674	1524.700	1477.709	-46.991
732.526	0.000143918056024	1004.567	1004.018	-0.549	2733.279	0.000335953903274	1531.501	1482.503	-48.998
752.696	0.000147418451159	1007.505	1007.432	-0.073	2757.260	0.000336832708280	1539.568	1489.196	-50.372
782.323	0.000152499400375	1011.948	1011.254	-0.694	2783.262	0.000337762173851	1548.339	1497.292	-51.047
809.041	0.000157018699730	1016.083	1015.565	-0.518	2810.670	0.000338716026317	1557.609	1504.319	-53.291
837.034	0.000161689032683	1020.544	1019.073	-1.471	2838.309	0.000339651557508	1566.984	1512.353	-54.631
857.170	0.000165007017853	1023.833	1022.852	-0.981	2859.972	0.000340366670895	1574.350	1519.220	-55.131
882.753	0.000169172152593	1028.108	1026.294	-1.814	2887.458	0.000341251402691	1583.717	1526.834	-56.883
908.363	0.000173284851021	1032.493	1031.885	-0.608	2911.043	0.000341990846332	1591.775	1534.916	-56.859
935.422	0.000177567679570	1037.240	1034.363	-2.877	2933.070	0.000342665222061	1599.315	1540.726	-58.589
956.725	0.000180894227273	1041.059	1038.713	-2.345	2956.504	0.000343365821548	1607.353	1548.725	-58.628
986.543	0.000185482991733	1046.521	1044.700	-1.821	2983.778	0.000344159700328	1616.729	1555.046	-61.683
1002.868	0.000187961803269	1049.570	1049.014	-0.556	3006.069	0.000344791616243	1624.408	1562.470	-61.938
1033.179	0.000192501229778	1055.336	1052.495	-2.841	3033.245	0.000345541869564	1633.788	1570.417	-63.372
1061.975	0.000196737999760	1060.940	1058.421	-2.519	3057.374	0.000346189773261	1642.134	1578.054	-64.080
1084.068	0.000199938284321	1065.322	1062.677	-2.645	3082.250	0.000346840048654	1650.753	1585.655	-65.099
1107.805	0.000203328148221	1070.108	1066.960	-3.148	3107.982	0.000347494236984	1659.687	1593.522	-66.165
1133.931	0.000207001119112	1075.469	1071.377	-4.092	3133.483	0.000348124287131	1668.556	1600.080	-68.477
1159.036	0.000210473198196	1080.709	1076.518	-4.191	3158.005	0.000348713367516	1677.100	1608.654	-68.446
1184.402	0.000213924429177	1086.092	1081.816	-4.276	3184.048	0.000349321274293	1686.190	1615.445	-70.745
1206.284	0.000216856014882	1090.805	1087.232	-3.573	3207.868	0.000349861598761	1694.517	1623.756	-70.761
1233.606	0.000220456971747	1096.780	1092.486	-4.294	3234.734	0.000350453374377	1703.925	1630.595	-73.330
1257.536	0.000223556987177	1102.092	1096.881	-5.212	3256.536	0.000350920064845	1711.570	1639.147	-72.423
1281.929	0.000226665522182	1107.583	1102.535	-5.049	3279.827	0.000351405481886	1719.749	1646.444	-73.305
1307.463	0.000229863997970	1113.412	1108.661	-4.751	3308.451	0.000351983785454	1729.816	1654.579	-75.237
1331.536	0.000232827928929	1118.981	1113.833	-5.148	3333.029	0.000352464526420	1738.473	1662.212	-76.261
1356.935	0.000235901364808	1124.934	1119.047	-5.888	3358.978	0.000352956561502	1747.626	1669.892	-77.734
1386.199	0.000239374247663	1131.888	1125.490	-6.399	3381.389	0.000353368871136	1755.540	1674.585	-80.955
1406.463	0.000241736868538	1136.763	1130.003	-6.760	3407.830	0.000353840555523	1764.890	1683.330	-81.560
1432.981	0.000244776599691	1143.214	1136.112	-7.102	3426.021	0.000354155935978	1771.330	1689.103	-82.227
1453.941	0.000247138064365	1148.369	1141.041	-7.328	3458.467	0.000354700278376	1782.830	1699.251	-83.579
1477.524	0.000249751742747	1154.228	1145.902	-8.326	3483.057	0.000355097581573	1791.556	1707.174	-84.382
1504.896	0.000252728706372	1161.106	1152.406	-8.700	3508.829	0.000355500171419	1800.713	1714.270	-86.443
1532.702	0.000255690940096	1168.174	1159.518	-8.656	3533.031	0.000355865588728	1809.322	1721.476	-87.846
1558.966	0.000258432447662	1174.926	1164.752	-10.174	3559.898	0.000356257137409	1818.888	1730.402	-88.486
1584.736	0.000261069697747	1181.620	1170.728	-10.891	3583.016	0.000356582388189	1827.128	1738.836	-88.291
1608.206	0.000263426573557	1187.775	1176.191	-11.583	3606.516	0.000356902145690	1835.511	1744.451	-91.060
1632.059	0.000265778683171	1194.087	1182.031	-12.056	3634.919	0.000357274256410	1845.654	1752.517	-93.137
1658.491	0.000268334474281	1201.145	1188.399	-12.747	3659.735	0.000357586719957	1854.524	1760.693	-93.831
1682.662	0.000270625902343	1207.659	1193.896	-13.763	3684.612	0.000357888322795	1863.423	1767.779	-95.644
1709.332	0.000273104148551	1214.910	1200.831	-14.079	3707.066	0.000358150741712	1871.462	1774.926	-96.536
1731.466	0.000275121407679	1220.977	1206.627	-14.350	3735.376	0.000358468542949	1881.606	1785.556	-96.050
1758.713	0.000277556210031	1228.507	1212.206	-16.300	3758.721	0.000358719841966	1889.977	1792.247	-97.731
1782.727	0.000279658373847	1235.197	1218.930	-16.267	3783.360	0.000358974702174	1898.819	1799.150	-99.669
1809.004	0.000281912512255	1242.576	1224.991	-17.584	3807.424	0.000359213512115	1907.460	1805.479	-101.981
1834.144	0.000284024422652	1249.689	1232.119	-17.570	3834.131	0.000359467058251	1917.057	1814.840	-102.217
1856.165	0.000285839005880	1255.964	1237.956	-18.008	3857.404	0.000359678318143	1925.425	1823.009	-102.416
1883.729	0.000288064598463	1263.874	1244.659	-19.214	3884.155	0.000359910200552	1935.050	1829.612	-105.439
1908.443	0.000290017468810	1271.017	1250.987	-20.030	3909.264	0.000360117373619	1944.090	1837.849	-106.242
1932.226	0.000291859189608	1277.936	1257.720	-20.216	3935.005	0.000360319414215	1953.362	1845.303	-108.060
1956.508	0.000293702269004	1285.046	1264.184	-20.861	3957.499	0.000360487544739	1961.469	1852.544	-108.925
1982.824	0.000295657784670	1292.801	1270.513	-22.288	3984.399	0.000360678461253	1971.169	1860.716	-110.453
2006.097	0.000297351315224	1299.701	1276.609	-23.093					

Table F.7a: Inhomogeneous Anisotropic Case: Forward modelling using a, b and χ estimates obtained from offset VSP times for segment 2 with receiver at 1974 m.

a = 1395.795218556840		b = 0.824486851129			χ = 0.058662431005		z = 1973.923		
offset (m)	p	computed time (ms)	observed time (ms)	residual (ms)	offset (m)	p	computed time (ms)	observed time (ms)	residual (ms)
84.530	0.000017329910318	938.133	935.707	-2.426	2011.513	0.000280040286497	1275.180	1269.025	-6.155
93.234	0.000019110451367	938.292	935.612	-2.679	2038.012	0.000281516676240	1282.620	1276.389	-6.232
112.705	0.000023089586999	938.703	936.244	-2.458	2058.654	0.000282635658262	1288.443	1281.452	-6.992
130.648	0.000026750301196	939.150	936.110	-3.040	2089.406	0.000284252986143	1297.160	1291.095	-6.065
152.613	0.000031222260499	939.786	937.377	-2.409	2113.127	0.000285460697563	1303.917	1297.340	-6.577
176.332	0.000036038365385	940.584	938.209	-2.376	2137.010	0.000286642234648	1310.749	1304.095	-6.654
200.664	0.000040962642667	941.521	939.183	-2.338	2162.001	0.000287842172773	1317.927	1308.005	-9.922
222.033	0.000045271895604	942.442	940.566	-1.876	2190.353	0.000289159295347	1326.107	1318.307	-7.800
244.406	0.000049766706703	943.506	941.458	-2.048	2208.538	0.000289979783243	1331.373	1324.103	-7.270
270.447	0.000054974329102	944.869	942.481	-2.388	2240.131	0.000291360834115	1340.556	1332.692	-7.864
293.032	0.000059467996324	946.162	944.033	-2.129	2262.848	0.000292319749642	1347.186	1340.505	-6.681
317.805	0.000064370727998	947.696	945.562	-2.134	2285.069	0.000293230560639	1353.692	1346.629	-7.063
343.415	0.000069407885206	949.409	947.720	-1.689	2313.522	0.000294358305796	1362.051	1354.231	-7.821
369.719	0.000074546239407	951.302	949.464	-1.838	2338.818	0.000295325303793	1369.509	1361.689	-7.820
393.092	0.000079080189968	953.098	952.038	-1.059	2364.031	0.000296256420375	1376.967	1368.898	-8.069
417.457	0.000083772868389	955.082	953.379	-1.703	2387.757	0.000297103367886	1384.006	1376.166	-7.840
443.392	0.000088728133628	957.319	956.346	-0.973	2414.140	0.000298012458876	1391.857	1384.134	-7.723
465.151	0.000092852259782	959.294	958.015	-1.279	2438.493	0.000298821632895	1399.124	1389.482	-9.642
493.184	0.000098119371242	961.971	960.078	-1.893	2462.794	0.000299600931577	1406.396	1396.500	-9.896
515.711	0.000102312420257	964.229	963.346	-0.883	2487.398	0.000300361832049	1413.776	1404.673	-9.104
541.511	0.000107070099529	966.930	965.572	-1.358	2515.010	0.000301182741805	1422.081	1412.021	-10.060
566.218	0.000111579857579	969.631	968.150	-1.481	2538.668	0.000301858895275	1429.215	1420.411	-8.804
594.084	0.000116610246374	972.811	971.846	-0.964	2561.908	0.000302499078695	1436.237	1425.506	-10.732
616.525	0.000120616774927	975.472	974.437	-1.036	2586.946	0.000303162690252	1443.820	1432.678	-11.142
640.390	0.000124833115341	978.401	977.709	-0.693	2611.466	0.000303786822369	1451.261	1439.409	-11.852
666.096	0.000129321806774	981.668	980.848	-0.821	2634.472	0.000304349670425	1458.257	1447.930	-10.326
686.674	0.000132875194322	984.366	983.892	-0.474	2664.740	0.000305057345433	1467.479	1457.009	-10.470
714.131	0.000137559493681	988.079	987.625	-0.454	2693.145	0.000305688264684	1476.154	1465.913	-10.241
734.065	0.000140919079624	990.854	990.735	-0.119	2713.475	0.000306120484055	1482.373	1471.688	-10.685
763.765	0.000145859212564	995.113	994.462	-0.651	2737.504	0.000306610936597	1489.734	1478.316	-11.418
790.341	0.000150212183263	999.048	998.943	-0.105	2763.498	0.000307117098271	1497.711	1486.156	-11.555
818.537	0.000154759932287	1003.347	1002.359	-0.988	2790.900	0.000307623778817	1506.133	1492.776	-13.357
838.613	0.000157953063371	1006.486	1006.107	-0.380	2818.515	0.000308107074099	1514.635	1501.544	-13.092
864.183	0.000161965405648	1010.577	1009.904	-0.673	2840.130	0.000308466624382	1521.299	1509.010	-12.290
889.644	0.000165899500085	1014.751	1015.459	0.708	2867.558	0.000308899645341	1529.766	1516.612	-13.154
916.870	0.000170038047132	1019.324	1018.333	-0.991	2891.097	0.000309250982640	1537.041	1522.475	-14.566
938.114	0.000173217919485	1022.970	1022.636	-0.334	2913.083	0.000309562558801	1543.844	1527.969	-15.875
967.871	0.000177599283121	1028.190	1028.093	-0.097	2936.480	0.000309876851949	1551.090	1537.739	-13.351
984.094	0.000179951771702	1031.090	1032.088	0.998	2963.685	0.000310220364141	1559.525	1544.497	-15.029
1014.404	0.000184278840546	1036.610	1035.925	-0.686	2985.984	0.000310484667314	1566.446	1551.710	-14.736
1043.220	0.000188310014723	1041.979	1041.995	0.016	3013.154	0.000310786155472	1574.886	1560.112	-14.774
1065.184	0.000191328210329	1046.148	1046.384	0.236	3037.280	0.000311035325070	1582.387	1566.471	-15.916
1088.895	0.000194533998826	1050.723	1050.471	-0.252	3062.143	0.000311274236486	1590.123	1575.806	-14.317
1115.015	0.000198002098427	1055.849	1055.210	-0.640	3087.867	0.000311502728359	1598.133	1582.710	-15.424
1140.098	0.000201270282873	1060.857	1060.235	-0.622	3113.355	0.000311710766688	1606.076	1587.800	-18.275
1165.295	0.000204491867701	1065.969	1065.256	-0.713	3137.870	0.000311893985178	1613.719	1597.852	-15.868
1187.085	0.000207228460487	1070.455	1070.389	-0.066	3163.910	0.000312070859714	1621.843	1605.218	-16.625
1214.352	0.000210588523019	1076.151	1075.694	-0.458	3187.722	0.000312216938835	1629.276	1614.170	-15.106
1238.248	0.000213474756061	1081.218	1080.502	-0.717	3214.578	0.000312364124515	1637.663	1620.041	-17.622
1262.578	0.000216357366083	1086.447	1085.769	-0.678	3236.351	0.000312470058344	1644.466	1627.195	-17.270
1288.093	0.000219320101677	1092.006	1092.119	0.113	3259.675	0.000312570500589	1651.755	1634.435	-17.320
1312.260	0.000222069775452	1097.339	1097.591	0.251	3288.287	0.000312675688636	1660.700	1645.422	-15.278
1337.566	0.000224890507786	1102.995	1102.887	-0.108	3312.831	0.000312750429104	1668.375	1651.273	-17.101
1366.579	0.000228051260168	1109.565	1110.075	0.510	3338.804	0.000312814296361	1676.499	1660.710	-15.788
1386.806	0.000230208993971	1114.200	1113.877	-0.323	3361.215	0.000312857079956	1683.510	1665.429	-18.081
1413.235	0.000232972138081	1120.321	1120.171	-0.150	3387.640	0.000312893174513	1691.778	1674.863	-16.915
1434.249	0.000235124029618	1125.239	1125.078	-0.162	3405.836	0.000312909170843	1697.471	1681.033	-16.438
1457.820	0.000237490678202	1130.810	1129.865	-0.945	3438.279	0.000312920165957	1707.623	1690.683	-16.940
1485.368	0.000240194003045	1137.389	1136.798	-0.591	3462.882	0.000312913854587	1715.322	1698.660	-16.662
1513.211	0.000242858647825	1144.114	1143.508	-0.607	3488.647	0.000312894022020	1723.384	1706.745	-16.639
1539.303	0.000245294562174	1150.483	1149.417	-1.066	3512.857	0.000312863325031	1730.958	1712.753	-18.206
1565.130	0.000247648256507	1156.849	1154.933	-1.916	3539.715	0.000312815900984	1739.361	1720.417	-18.944
1588.644	0.000249741966588	1162.696	1160.874	-1.822	3562.825	0.000312764079935	1746.589	1742.573	-4.017
1612.475	0.000251816713427	1168.673	1167.062	-1.611	3586.331	0.000312701143023	1753.941	1738.627	-15.313
1638.883	0.000254060999151	1175.353	1173.549	-1.804	3614.704	0.000312611739390	1762.812	1743.987	-18.824
1663.079	0.000256067287416	1181.524	1178.955	-2.569	3639.544	0.000312521670687	1770.576	1750.378	-20.198
1689.771	0.000258225864047	1188.388	1185.425	-2.963	3664.411	0.000312420727300	1778.346	1773.884	-4.462
1711.871	0.000259970263275	1194.114	1191.324	-2.791	3686.858	0.000312320542691	1785.358	1767.780	-17.578
1739.048	0.000262062866242	1201.208	1197.521	-3.687	3715.162	0.000312182231457	1794.196	1773.923	-20.272
1763.081	0.000263865901538	1207.528	1203.817	-3.711	3738.511	0.000312058290879	1801.483	1782.683	-18.801
1789.370	0.000265787775552	1214.490	1210.837	-3.653	3763.146	0.000311918097989	1809.169	1802.645	-6.524
1814.387	0.000267568574479	1221.162	1217.784	-3.378	3787.190	0.000311772129596	1816.667	1796.954	-19.713
1836.461	0.000269101427122	1227.085	1223.474	-3.611	3813.895	0.000311599671851	1824.991	1807.817	-17.174
1863.985	0.000270963184942	1234.518	1231.080	-3.438	3837.164	0.000311440733716	1832.240	1825.078	-7.162
1888.688	0.000272587819987	1241.231	1235.614	-5.617	3863.906	0.000311248321566	1840.566	1823.494	-17.072
1912.386	0.000274105960012	1247.709	1242.405	-5.304	3889.009	0.000311058431748	1848.377	1820.780	-27.597
1936.696	0.000275622728014	1254.391	1250.340	-4.051	3914.736	0.000310854733338	1856.377	1833.245	-23.132
1962.993	0.000277218103783	1261.660	1255.989	-5.672	3937.224	0.000310669307833	1863.365	1860.562	-2.803
1986.236	0.000278589467350	1268.120	1262.363	-5.757	3964.125	0.000310438667108	1871.719	1870.558	-1.161

Table F.7b: Inhomogeneous Anisotropic Case: Forward modelling using a, b and χ estimates obtained from offset VSP times for segment 2 with receiver at 2014 m.

a = 1395.795218556840		b = 0.824486851129			χ = 0.058662431005		z = 2013.927		
offset (m)	p	computed time (ms)	observed time (ms)	residual (ms)	offset (m)	p	computed time (ms)	observed time (ms)	residual (ms)
47.917	0.000009563428875	950.790	949.852	-0.938	2031.400	0.000276414586196	1286.611	1283.866	-2.745
67.679	0.000013503726036	951.018	950.437	-0.581	2057.867	0.000277872705905	1293.946	1290.939	-3.008
87.531	0.000017457823207	951.325	950.647	-0.678	2078.568	0.000278982912614	1299.710	1296.333	-3.377
114.917	0.000022903917748	951.878	951.544	-0.334	2109.336	0.000280584833493	1308.319	1305.118	-3.201
136.226	0.000027132828561	952.411	951.374	-1.037	2133.030	0.000281779776954	1314.981	1311.261	-3.720
159.548	0.000031750642524	953.098	953.025	-0.073	2156.926	0.000282951473938	1321.729	1317.697	-4.032
185.804	0.000036933823471	953.999	953.865	-0.134	2181.962	0.000284143594306	1328.827	1322.426	-6.402
210.975	0.000041885118145	954.991	954.950	-0.041	2210.257	0.000285448071070	1336.886	1332.953	-3.933
234.325	0.000046460572982	956.023	956.605	0.582	2228.452	0.000286263302953	1342.087	1338.401	-3.686
258.040	0.000051088504470	957.180	957.373	0.193	2260.084	0.000287637318376	1351.164	1346.712	-4.452
284.557	0.000056238259886	958.603	958.386	-0.217	2282.716	0.000288587312011	1357.685	1353.271	-4.413
307.433	0.000060657802210	959.940	960.111	0.171	2304.890	0.000289491799270	1364.094	1359.676	-4.418
332.872	0.000065545385309	961.545	961.630	0.085	2333.394	0.000290616902514	1372.362	1367.060	-5.302
359.049	0.000070542804574	963.326	963.944	0.617	2358.739	0.000291582469641	1379.739	1375.573	-4.167
385.343	0.000075527619010	965.247	965.418	0.171	2383.962	0.000292511496534	1387.106	1382.318	-4.788
409.334	0.000080043754202	967.113	968.447	1.334	2407.702	0.000293357339911	1394.060	1389.120	-4.941
433.705	0.000084598091112	969.119	969.921	0.801	2434.097	0.000294265849624	1401.816	1396.500	-5.315
460.001	0.000089472636133	971.408	972.838	1.430	2458.515	0.000295076910246	1409.011	1403.233	-5.778
482.029	0.000093523239632	973.424	974.457	1.033	2482.793	0.000295855874083	1416.184	1410.509	-5.675
509.907	0.000098604737663	976.102	976.609	0.507	2507.442	0.000296619236809	1423.486	1418.106	-5.380
532.777	0.000102734469947	978.404	979.967	1.563	2535.041	0.000297441697078	1431.684	1425.056	-6.628
558.748	0.000107380506656	981.133	981.933	0.800	2558.701	0.000298120169548	1438.730	1432.211	-6.518
583.493	0.000111762281830	983.844	985.107	1.262	2581.986	0.000298764347649	1445.679	1439.055	-6.624
611.554	0.000116676614480	987.050	988.531	1.481	2607.071	0.000299432682684	1453.182	1445.480	-7.702
634.129	0.000120586854456	989.728	991.086	1.358	2631.588	0.000300060666974	1460.531	1452.599	-7.932
658.248	0.000124720933387	992.686	994.422	1.736	2654.653	0.000300629123804	1467.458	1459.835	-7.624
684.072	0.000129096064939	995.964	997.434	1.471	2684.768	0.000301339380646	1476.522	1469.199	-7.324
705.124	0.000132622793294	998.718	1000.876	2.158	2713.012	0.000301973325349	1485.042	1477.709	-7.333
732.526	0.000137158411645	1002.415	1004.018	1.604	2733.279	0.000302409431858	1491.167	1482.503	-8.664
752.696	0.000140456921246	1005.215	1007.432	2.218	2757.260	0.000302905532230	1498.425	1489.196	-9.229
782.323	0.000145239109564	1009.447	1011.254	1.807	2783.262	0.000303419505718	1506.308	1497.292	-9.016
809.041	0.000149486662820	1013.384	1015.565	2.181	2810.670	0.000303934854832	1514.631	1504.319	-10.313
837.034	0.000153869855046	1017.631	1019.073	1.443	2838.309	0.000304427679220	1523.038	1512.353	-10.685
857.170	0.000156979734771	1020.760	1022.852	2.092	2859.972	0.000304795478950	1529.638	1519.220	-10.418
882.753	0.000160878542810	1024.826	1026.294	1.468	2887.458	0.000305239216528	1538.021	1526.834	-11.187
908.363	0.000164722428873	1028.996	1031.885	2.889	2911.043	0.000305599969237	1545.225	1534.916	-10.309
935.422	0.000168718817825	1033.507	1034.363	0.856	2933.070	0.000305920498660	1551.960	1540.726	-11.234
956.725	0.000171818064664	1037.134	1038.713	1.579	2956.504	0.000306244470788	1559.132	1548.725	-10.407
986.543	0.000176085991771	1042.322	1044.700	2.378	2983.778	0.000306599837212	1567.490	1555.046	-12.444
1002.868	0.000178387809907	1045.215	1049.014	3.799	3006.069	0.000306873275951	1574.327	1562.470	-11.857
1033.179	0.000182596066268	1050.686	1052.495	1.809	3033.245	0.000307186406052	1582.671	1570.417	-12.255
1061.975	0.000186515101414	1056.001	1058.421	2.420	3057.374	0.000307446163088	1590.087	1578.054	-12.032
1084.068	0.000189469542222	1060.154	1062.677	2.523	3082.250	0.000307696322724	1597.737	1585.655	-12.083
1107.805	0.000192593240990	1064.689	1066.960	2.272	3107.982	0.000307936665325	1605.658	1593.522	-12.137
1133.931	0.000195970807571	1069.765	1071.377	1.612	3133.483	0.000308156718937	1613.514	1600.080	-13.434
1159.036	0.000199156598290	1074.725	1076.518	1.793	3158.005	0.000308351673394	1621.073	1608.654	-12.419
1184.402	0.000202316131063	1079.816	1081.816	2.000	3184.048	0.000308541208431	1629.106	1615.445	-13.661
1206.284	0.000204994087625	1084.273	1087.232	2.959	3207.868	0.000308699092987	1636.457	1623.756	-12.701
1233.606	0.000208275784224	1089.919	1092.486	2.567	3234.734	0.000308859808290	1644.753	1630.595	-14.158
1257.536	0.000211093806210	1094.937	1096.881	1.944	3256.536	0.000308976966888	1651.488	1639.147	-12.341
1281.929	0.000213912602179	1100.120	1102.535	2.414	3279.827	0.000309089267394	1658.686	1646.444	-12.241
1307.463	0.000216805316419	1105.620	1108.661	3.041	3308.451	0.000309209460966	1667.535	1654.579	-12.956
1331.536	0.000219478655420	1110.871	1113.833	2.962	3333.029	0.000309297308945	1675.136	1662.212	-12.924
1356.935	0.000222243034967	1116.481	1119.047	2.566	3358.978	0.000309375007293	1683.163	1669.892	-13.271
1386.199	0.000225356739309	1123.030	1125.490	2.460	3381.389	0.000309429920568	1690.097	1674.585	-15.511
1406.463	0.000227468678214	1127.618	1130.003	2.385	3407.830	0.000309480487467	1698.279	1683.330	-14.949
1432.981	0.000230177971268	1133.686	1136.112	2.425	3426.021	0.000309506506520	1703.909	1689.103	-14.806
1453.941	0.000232276315511	1138.533	1141.041	2.508	3458.467	0.000309535549448	1713.952	1699.251	-14.701
1477.524	0.000234591932334	1144.038	1145.902	1.864	3483.057	0.000309543052571	1721.563	1707.174	-14.389
1504.896	0.000237220247642	1150.496	1152.406	1.910	3508.829	0.000309537805639	1729.541	1714.270	-15.270
1532.702	0.000239825386588	1157.128	1159.518	2.390	3533.031	0.000309520919398	1737.032	1721.476	-15.557
1558.966	0.000242226893863	1163.458	1164.752	1.293	3559.898	0.000309488905012	1745.348	1730.402	-14.946
1584.736	0.000244528000946	1169.730	1170.728	0.998	3583.016	0.000309450419191	1752.502	1738.836	-13.666
1608.206	0.000246576578246	1175.493	1176.191	0.698	3606.516	0.000309401145362	1759.773	1744.451	-15.322
1632.059	0.000248613240065	1181.400	1182.031	0.631	3634.919	0.000309328222203	1768.561	1752.517	-16.044
1658.491	0.000250817050650	1188.000	1188.399	0.399	3659.735	0.000309252799936	1776.236	1760.693	-15.543
1682.662	0.000252784357967	1194.086	1193.896	-0.190	3684.612	0.000309166480866	1783.928	1767.779	-16.149
1709.332	0.000254902513497	1200.857	1200.831	-0.026	3707.066	0.000309079546507	1790.869	1774.926	-15.943
1731.466	0.000256619001459	1206.518	1206.627	0.109	3735.376	0.000308958014391	1799.618	1785.556	-14.061
1758.713	0.000258681175992	1213.538	1212.206	-1.332	3758.721	0.000308848006194	1806.829	1792.247	-14.582
1782.727	0.000260452778608	1219.771	1218.930	-0.841	3783.360	0.000308722515387	1814.437	1799.150	-15.287
1809.004	0.000262342907066	1226.640	1224.991	-1.649	3807.424	0.000308590843981	1821.865	1805.479	-16.385
1834.144	0.000264104377697	1233.258	1232.119	-1.139	3834.131	0.000308434409419	1830.104	1814.840	-15.264
1856.165	0.000265610258487	1239.090	1237.956	-1.134	3857.404	0.000308289441328	1837.281	1823.009	-14.272
1883.729	0.000267447181312	1246.437	1244.659	-1.778	3884.155	0.000308113086308	1845.525	1829.612	-15.914
1908.443	0.000269049463950	1253.067	1250.987	-2.080	3909.264	0.000307938310545	1853.260	1837.849	-15.411
1932.226	0.000270551981614	1259.483	1257.720	-1.763	3935.005	0.000307750060177	1861.184	1845.303	-15.881
1956.508	0.000272046895760	1266.071	1264.184	-1.887	3957.499	0.000307578189677	1868.104	1852.544	-15.560
1982.824	0.000273623027989	1273.251	1270.513	-2.738	3984.399	0.000307363842074	1876.375	1860.716	-15.659
2006.097	0.000274979311207	1279.635	1276.609	-3.026					

Table F.8a: Inhomogeneous Anisotropic Case: Forward modelling using a, b and χ estimates obtained from offset VSP times for segment 3 with receiver at 1974 m.

a = 1275.727651271120		b = 0.991031560690			χ = 0.045011486195		z = 1973.923		
offset (m)	p	computed time (ms)	observed time (ms)	residual (ms)	offset (m)	p	computed time (ms)	observed time (ms)	residual (ms)
84.530	0.000017413594550	938.717	935.707	-3.010	2011.513	0.000273327501561	1272.425	1269.025	-3.400
93.234	0.000019202452677	938.876	935.612	-3.264	2038.012	0.000274600433128	1279.685	1276.389	-3.297
112.705	0.000023199865313	939.289	936.244	-3.045	2058.654	0.000275560135536	1285.364	1281.452	-3.912
130.648	0.000026876955133	939.738	936.110	-3.628	2089.406	0.000276938995057	1293.859	1291.095	-2.764
152.613	0.000031368246441	940.378	937.377	-3.001	2113.127	0.000277961854453	1300.440	1297.340	-3.101
176.332	0.000036204208528	941.179	938.209	-2.971	2137.010	0.000278956544946	1307.091	1304.095	-2.996
200.664	0.000041147596040	942.120	939.183	-2.938	2162.001	0.000279960254583	1314.075	1308.005	-6.070
222.033	0.000045472449116	943.046	940.566	-2.480	2190.353	0.000281053944259	1322.028	1318.307	-3.721
244.406	0.000049982283185	944.114	941.458	-2.656	2208.538	0.000281730709470	1327.145	1324.103	-3.042
270.447	0.000055205541812	945.483	942.481	-3.002	2240.131	0.000282861395072	1336.064	1332.692	-3.372
293.032	0.000059711019831	946.781	944.033	-2.748	2262.848	0.000283639799769	1342.499	1340.505	-1.994
317.805	0.000064624688042	948.321	945.562	-2.759	2285.069	0.000284373708916	1348.810	1346.629	-2.181
343.415	0.000069670773706	950.041	947.720	-2.321	2313.522	0.000285274524553	1356.914	1354.231	-2.683
369.719	0.000074815614082	951.941	949.464	-2.478	2338.818	0.000286039443048	1364.140	1361.689	-2.451
393.092	0.000079352911295	953.743	952.038	-1.705	2364.031	0.000286768897092	1371.361	1368.898	-2.463
417.457	0.000084046530893	955.734	953.379	-2.355	2387.757	0.000287425899608	1378.173	1376.166	-2.006
443.392	0.000088999806663	957.978	956.346	-1.632	2414.140	0.000288123638338	1385.765	1384.134	-1.631
465.151	0.000093119785342	959.959	958.015	-1.944	2438.493	0.000288737643225	1392.789	1389.482	-3.307
493.184	0.000098378087702	962.644	960.078	-2.566	2462.794	0.000289322168006	1399.813	1396.500	-3.313
515.711	0.000102561134146	964.907	963.346	-1.561	2487.398	0.000289885894324	1406.939	1404.673	-2.266
541.511	0.000107304052376	967.614	965.572	-2.042	2515.010	0.000290485614692	1414.951	1412.021	-2.930
566.218	0.000111796275579	970.321	968.150	-2.171	2538.668	0.000290972369261	1421.829	1420.411	-1.419
594.084	0.000116802789647	973.506	971.846	-1.660	2561.908	0.000291426661165	1428.597	1425.506	-3.091
616.525	0.000120786862759	976.172	974.437	-1.736	2586.946	0.000291890208830	1435.899	1432.678	-3.221
640.390	0.000124976097795	979.105	977.709	-1.396	2611.466	0.000292318673009	1443.062	1439.409	-3.653
666.096	0.000129431814580	982.375	980.848	-1.527	2634.472	0.000292698209739	1449.791	1447.930	-1.861
686.674	0.000132955937010	985.075	983.892	-1.183	2664.740	0.000293165167712	1458.658	1457.009	-1.649
714.131	0.000137597169253	988.789	987.625	-1.164	2693.145	0.000293570716598	1466.991	1465.913	-1.078
734.065	0.000140922578114	991.565	990.735	-0.830	2713.475	0.000293841990950	1472.962	1471.688	-1.274
763.765	0.000145807203944	995.823	994.462	-1.362	2737.504	0.000294142633918	1480.027	1478.316	-1.710
790.341	0.000150105820233	999.756	998.943	-0.813	2763.498	0.000294444001919	1487.676	1486.156	-1.520
818.537	0.000154591029895	1004.051	1002.359	-1.692	2790.900	0.000294735452183	1495.749	1492.776	-2.972
838.613	0.000157736565259	1007.187	1006.107	-1.080	2818.515	0.000295002574784	1503.892	1501.544	-2.348
864.183	0.000161684585057	1011.271	1009.904	-1.367	2840.130	0.000295193461914	1510.270	1509.010	-1.261
889.644	0.000165550505187	1015.437	1015.459	0.022	2867.558	0.000295413196827	1518.370	1516.612	-1.758
916.870	0.000169611604726	1019.999	1018.333	-1.666	2891.097	0.000295582168688	1525.326	1522.475	-2.851
938.114	0.000172727790797	1023.636	1022.636	-1.000	2913.083	0.000295723999208	1531.826	1527.969	-3.857
967.871	0.000177015160541	1028.840	1028.093	-0.746	2936.480	0.000295858312530	1538.747	1537.739	-1.008
984.094	0.000179314068670	1031.730	1032.088	0.358	2963.685	0.000295993426883	1546.798	1544.497	-2.301
1014.404	0.000183536632630	1037.229	1035.925	-1.305	2985.984	0.000296087656542	1553.399	1551.710	-1.689
1043.220	0.000187463182044	1042.575	1041.995	-0.580	3013.154	0.000296182841104	1561.445	1560.112	-1.333
1065.184	0.000190398221240	1046.724	1046.384	-0.340	3037.280	0.000296249697852	1568.591	1566.471	-2.121
1088.895	0.000193510951010	1051.276	1050.471	-0.806	3062.143	0.000296301621727	1575.958	1575.806	-0.152
1115.015	0.000196872638882	1056.375	1055.210	-1.165	3087.867	0.000296337630921	1583.580	1582.710	-0.871
1140.098	0.000200034830404	1061.353	1060.235	-1.118	3113.355	0.000296355965042	1591.134	1587.800	-3.333
1165.295	0.000203146245076	1066.432	1065.256	-1.176	3137.870	0.000296357698345	1598.399	1597.852	-0.547
1187.085	0.000205784615494	1070.888	1070.389	-0.499	3163.910	0.000296342873308	1606.116	1605.218	-0.898
1214.352	0.000209017977982	1076.543	1075.694	-0.849	3187.722	0.000296314642529	1613.172	1614.170	0.998
1238.248	0.000211789761603	1081.571	1080.502	-1.070	3214.578	0.000296266391863	1621.129	1620.041	-1.088
1262.578	0.000214552636599	1086.758	1085.769	-0.989	3236.351	0.000296214800984	1627.579	1627.195	-0.384
1288.093	0.000217386388841	1092.268	1092.119	-0.149	3259.675	0.000296147432782	1634.487	1634.435	-0.053
1312.260	0.000220010730922	1097.554	1097.591	0.037	3288.287	0.000296048092463	1642.960	1645.422	2.463
1337.566	0.000222696995141	1103.155	1102.887	-0.268	3312.831	0.000295948585469	1650.224	1651.273	1.049
1366.579	0.000225699613392	1109.660	1110.075	0.415	3338.804	0.000295829275148	1657.910	1660.710	2.801
1386.806	0.000227744648859	1114.246	1113.877	-0.369	3361.215	0.000295715031928	1664.538	1665.429	0.890
1413.235	0.000230357572653	1120.300	1120.171	-0.129	3387.640	0.000295567205338	1672.351	1674.863	2.512
1434.249	0.000232387680668	1125.162	1125.078	-0.084	3405.836	0.000295457347542	1677.728	1681.033	3.305
1457.820	0.000234615316748	1130.666	1129.865	-0.801	3438.279	0.000295245553088	1687.310	1690.683	3.373
1485.368	0.000237153036685	1137.164	1136.798	-0.366	3462.882	0.000295071692029	1694.572	1698.660	4.088
1513.211	0.000239646954801	1143.802	1143.508	-0.295	3488.647	0.000294877695009	1702.172	1706.745	4.573
1539.303	0.000241919931177	1150.085	1149.417	-0.668	3512.857	0.000294684580387	1709.308	1712.753	3.444
1565.130	0.000244109617888	1156.361	1154.933	-1.428	3539.715	0.000294458382909	1717.220	1720.417	3.197
1588.644	0.000246051728773	1162.124	1160.874	-1.250	3562.825	0.000294253929165	1724.023	1742.573	18.550
1612.475	0.000247970679820	1168.011	1167.062	-0.949	3586.331	0.000294036889039	1730.937	1738.627	7.690
1638.883	0.000250039874935	1174.587	1173.549	-1.038	3614.704	0.000293763031711	1739.276	1743.987	4.712
1663.079	0.000251883562561	1180.659	1178.955	-1.704	3639.544	0.000293512878447	1746.570	1750.378	3.808
1689.771	0.000253860436553	1187.409	1185.425	-1.984	3664.411	0.000293253001074	1753.865	1773.884	20.019
1711.871	0.000255452610048	1193.037	1191.324	-1.713	3686.858	0.000293010491595	1760.445	1767.780	7.335
1739.048	0.000257355897586	1200.005	1197.521	-2.485	3715.162	0.000292694274821	1768.734	1773.923	5.189
1763.081	0.000258989635472	1206.210	1203.817	-2.393	3738.511	0.000292424886694	1775.565	1782.683	7.118
1789.370	0.000260724394635	1213.042	1210.837	-2.204	3763.146	0.000292132531953	1782.765	1802.645	19.880
1814.387	0.000262325334751	1219.584	1217.784	-1.801	3787.190	0.000291839335398	1789.786	1796.954	7.168
1836.461	0.000263698102907	1225.390	1223.474	-1.916	3813.895	0.000291504856838	1797.575	1807.817	10.242
1863.985	0.000265358498079	1232.671	1231.080	-1.592	3837.164	0.000291206037733	1804.354	1825.078	20.723
1888.688	0.000266800850331	1239.244	1235.614	-3.630	3863.906	0.000290854350310	1812.137	1823.494	11.357
1912.386	0.000268142795583	1245.583	1242.405	-3.178	3889.009	0.000290516399625	1819.435	1820.780	1.345
1936.696	0.000269477547893	1252.117	1250.340	-1.778	3914.736	0.000290162429513	1826.904	1833.245	6.340
1962.993	0.000270874639934	1259.223	1255.989	-3.234	3937.224	0.000289846868769	1833.426	1860.562	27.136
1986.236	0.000272069624394	1265.532	1262.363	-3.170	3964.125	0.000289462050025	1841.218	1870.558	29.341

Table F.8b: Inhomogeneous Anisotropic Case: Forward modelling using a, b and χ estimates obtained from offset VSP times for segment 3 with receiver at 2014 m.

$a =$ 1275.727651271120		$b =$ 0.991031560690			$\chi =$ 0.045011486195		$z =$ 2013.927		
offset (m)	p	computed time (ms)	observed time (ms)	residual (ms)	offset (m)	p	computed time (ms)	observed time (ms)	residual (ms)
47.917	0.000009597374003	950.513	949.852	-0.661	2031.400	0.000269477929025	1282.605	1283.866	1.261
67.679	0.000013551372420	950.742	950.437	-0.304	2057.867	0.000270736300021	1289.754	1290.939	1.185
87.531	0.000017518924975	951.050	950.647	-0.403	2078.568	0.000271689536234	1295.368	1296.333	0.965
114.917	0.000022982910238	951.605	951.544	-0.061	2109.336	0.000273057035682	1303.749	1305.118	1.369
136.226	0.000027225069039	952.140	951.374	-0.766	2133.030	0.000274070623295	1310.231	1311.261	1.030
159.548	0.000031856567481	952.829	953.025	0.196	2156.926	0.000275058740235	1316.792	1317.697	0.905
185.804	0.000037053965192	953.733	953.865	0.132	2181.962	0.000276057860980	1323.690	1322.426	-1.265
210.975	0.000042017531823	954.728	954.950	0.222	2210.257	0.000277143461824	1331.517	1332.953	1.436
234.325	0.000046603032428	955.763	956.605	0.842	2228.452	0.000277817563466	1336.566	1338.401	1.836
258.040	0.000051239709169	956.923	957.373	0.450	2260.084	0.000278945604024	1345.372	1346.712	1.341
284.557	0.000056397338438	958.350	958.386	0.035	2282.716	0.000279719171955	1351.694	1353.271	1.578
307.433	0.000060821922417	959.691	960.111	0.419	2304.890	0.000280450498439	1357.904	1359.676	1.772
332.872	0.000065713061630	961.301	961.630	0.329	2333.394	0.000281352638348	1365.911	1367.060	1.149
359.049	0.000070711732476	963.086	963.944	0.857	2358.739	0.000282119661133	1373.052	1375.573	2.521
385.343	0.000075695188041	965.011	965.418	0.406	2383.962	0.000282850876211	1380.177	1382.318	2.141
409.334	0.000080207666384	966.882	968.447	1.566	2407.702	0.000283510389113	1386.900	1389.120	2.220
433.705	0.000084755809671	968.892	969.921	1.029	2434.097	0.000284211619738	1394.392	1396.500	2.108
460.001	0.000089620743727	971.185	972.838	1.653	2458.515	0.000284830878033	1401.340	1403.233	1.893
482.029	0.000093660863360	973.203	974.457	1.253	2482.793	0.000285419129935	1408.262	1410.509	2.247
509.907	0.000098725794113	975.885	976.609	0.724	2507.442	0.000285988908045	1415.304	1418.106	2.802
532.777	0.000102839094265	978.190	979.967	1.777	2535.041	0.000286594723762	1423.206	1425.056	1.850
558.748	0.000107463268028	980.921	981.933	1.012	2558.701	0.000287087606435	1429.993	1432.211	2.218
583.493	0.000111820960993	983.634	985.107	1.472	2581.986	0.000287549301929	1436.683	1439.055	2.372
611.554	0.000116704047358	986.841	988.531	1.690	2607.071	0.000288021270694	1443.902	1445.480	1.578
634.129	0.000120586047398	989.519	991.086	1.566	2631.588	0.000288457599563	1450.969	1452.599	1.630
658.248	0.000124686839373	992.477	994.422	1.945	2654.653	0.000288846027576	1457.627	1459.835	2.208
684.072	0.000129022706676	995.753	997.434	1.681	2684.768	0.000289321690745	1466.333	1469.199	2.866
705.124	0.000132514614962	998.506	1000.876	2.370	2713.012	0.000289736148143	1474.510	1477.709	3.199
732.526	0.000137001082576	1002.199	1004.018	1.819	2733.279	0.000290015102455	1480.385	1482.503	2.118
752.696	0.000140260617631	1004.995	1007.432	2.437	2757.260	0.000290325665409	1487.344	1489.196	1.853
782.323	0.000144981223232	1009.221	1011.254	2.033	2783.262	0.000290639001536	1494.897	1497.292	2.395
809.041	0.000149168786763	1013.151	1015.565	2.414	2810.670	0.000290943514117	1502.867	1504.319	1.452
837.034	0.000153484568445	1017.387	1019.073	1.686	2838.309	0.000291224446651	1510.912	1512.353	1.441
857.170	0.000156543066667	1020.508	1022.852	2.344	2859.972	0.000291426700969	1517.223	1519.220	1.996
882.753	0.000160373096215	1024.562	1026.294	1.732	2887.458	0.000291661124461	1525.237	1526.834	1.597
908.363	0.000164144207724	1028.718	1031.885	3.167	2911.043	0.000291842932914	1532.118	1534.916	2.798
935.422	0.000168059450971	1033.212	1034.363	1.151	2933.070	0.000291996931697	1538.548	1540.726	2.178
956.725	0.000171091741750	1036.825	1038.713	1.888	2956.504	0.000292144373679	1545.392	1548.725	3.333
986.543	0.000175261427370	1041.989	1044.700	2.711	2983.778	0.000292295150627	1553.362	1555.046	1.683
1002.868	0.000177507236237	1044.869	1049.014	4.145	3006.069	0.000292402104354	1559.879	1562.470	2.591
1033.179	0.000181607355804	1050.311	1052.495	2.183	3033.245	0.000292513162491	1567.827	1570.417	2.590
1061.975	0.000185418703340	1055.596	1058.421	2.825	3057.374	0.000292594359354	1574.886	1578.054	3.168
1084.068	0.000188287286415	1059.724	1062.677	2.953	3082.250	0.000292661317125	1582.165	1585.655	3.490
1107.805	0.000191315636444	1064.230	1066.960	2.731	3107.982	0.000292713101397	1589.697	1593.522	3.825
1133.931	0.000194584582748	1069.271	1071.377	2.106	3133.483	0.000292747289739	1597.162	1600.080	2.918
1159.036	0.000197662418723	1074.195	1076.518	2.323	3158.005	0.000292764460818	1604.341	1608.654	4.314
1184.402	0.000200709361471	1079.247	1081.816	2.569	3184.048	0.000292766233278	1611.965	1615.445	3.479
1206.284	0.000203287387987	1083.668	1087.232	3.565	3207.868	0.000292753349171	1618.939	1623.756	4.817
1233.606	0.000206440733775	1089.265	1092.486	3.220	3234.734	0.000292722585179	1626.804	1630.595	3.791
1257.536	0.000209143126044	1094.238	1096.881	2.643	3256.536	0.000292685261635	1633.185	1639.147	5.962
1281.929	0.000211841019826	1099.372	1102.535	3.163	3279.827	0.000292633432728	1640.001	1646.444	6.443
1307.463	0.000214603959863	1104.817	1108.661	3.844	3308.451	0.000292553211119	1648.377	1654.579	6.202
1331.536	0.000217151992337	1110.014	1113.833	3.819	3333.029	0.000292470147329	1655.566	1662.212	6.646
1356.935	0.000219781111714	1115.563	1119.047	3.484	3358.978	0.000292368582751	1663.154	1669.892	6.737
1386.199	0.000222735193286	1122.038	1125.490	3.452	3381.389	0.000292269677480	1669.705	1674.585	4.880
1406.463	0.000224734270800	1126.572	1130.003	3.432	3407.830	0.000292139966850	1677.431	1683.330	5.898
1432.981	0.000227293077359	1132.565	1136.112	3.546	3426.021	0.000292042720006	1682.745	1689.103	6.358
1453.941	0.000229270273429	1137.350	1141.041	3.691	3458.467	0.000291853479652	1692.218	1699.251	7.033
1477.524	0.000231447325883	1142.783	1145.902	3.119	3483.057	0.000291696912638	1699.392	1707.174	7.782
1504.896	0.000233911880552	1149.152	1152.406	3.254	3508.829	0.000291520976695	1706.908	1714.270	7.363
1532.702	0.000236347545806	1155.690	1159.518	3.828	3533.031	0.000291344994244	1713.961	1721.476	7.515
1558.966	0.000238586172868	1161.927	1164.752	2.825	3559.898	0.000291137741363	1721.786	1730.402	8.616
1584.736	0.000240724900807	1168.103	1170.728	2.626	3583.016	0.000290949633922	1728.514	1738.836	10.322
1608.206	0.000242623459665	1173.775	1176.191	2.416	3606.516	0.000290749380045	1735.349	1744.451	9.102
1632.059	0.000244505624984	1179.585	1182.031	2.446	3634.919	0.000290495483665	1743.604	1752.517	8.913
1658.491	0.000246535946155	1186.075	1188.399	2.324	3659.735	0.000290263312711	1750.810	1760.693	9.883
1682.662	0.000248342553192	1192.056	1193.896	1.841	3684.612	0.000290021150994	1758.028	1767.779	9.751
1709.332	0.000250281207638	1198.705	1200.831	2.126	3707.066	0.000289794658569	1764.537	1774.926	10.389
1731.466	0.000251847052538	1204.262	1206.627	2.365	3735.376	0.000289498689568	1772.737	1785.556	12.819
1758.713	0.000253721780528	1211.150	1212.206	1.057	3758.721	0.000289246117155	1779.493	1792.247	12.754
1782.727	0.000255326416825	1217.262	1218.930	1.669	3783.360	0.000288971420626	1786.616	1799.150	12.534
1809.004	0.000257032023101	1223.994	1224.991	0.997	3807.424	0.000288695278147	1793.567	1805.479	11.913
1834.144	0.000258615269150	1230.476	1232.119	1.643	3834.131	0.000288379964907	1801.272	1814.840	13.568
1856.165	0.000259963734615	1236.185	1237.956	1.771	3857.404	0.000288097800131	1807.981	1823.009	15.028
1883.729	0.000261601980122	1243.374	1244.659	1.286	3884.155	0.000287765193783	1815.683	1829.612	13.928
1908.443	0.000263024653043	1249.857	1250.987	1.130	3909.264	0.000287445175117	1822.905	1837.849	14.944
1932.226	0.000264353090030	1256.128	1257.720	1.592	3935.005	0.000287109457510	1830.299	1845.303	15.003
1956.508	0.000265669066572	1262.563	1264.184	1.621	3957.499	0.000286809904259	1836.754	1852.544	15.789
1982.824	0.000267049978961	1269.573	1270.513	0.940	3984.399	0.000286444320225	1844.465	1860.716	16.252
2006.097	0.000268232565101	1275.802	1276.609	0.807					

Table F.9a: Inhomogeneous Anisotropic Case: Forward modelling using *a*, *b* and χ estimates obtained from offset VSP times for segment 4 with receiver at 1974 m.

a = 1347.931539688680		b = 0.884981169823			χ = 0.065305746933		z = 1973.923		
offset (m)	p	computed time (ms)	observed time (ms)	residual (ms)	offset (m)	p	computed time (ms)	observed time (ms)	residual (ms)
84.530	0.000017034880302	939.901	935.707	-4.194	2011.513	0.000274122629927	1270.614	1269.025	-1.589
93.234	0.000018785090694	940.057	935.612	-4.445	2038.012	0.000275533305612	1277.897	1276.389	-1.508
112.705	0.000022696423500	940.461	936.244	-4.217	2058.654	0.000276601210772	1283.596	1281.452	-2.144
130.648	0.000026294731928	940.900	936.110	-4.790	2089.406	0.000278142634885	1292.125	1291.095	-1.031
152.613	0.000030690411467	941.526	937.377	-4.149	2113.127	0.000279291948329	1298.737	1297.340	-1.397
176.332	0.000035424302294	942.310	938.209	-4.102	2137.010	0.000280414823679	1305.421	1304.095	-1.326
200.664	0.000040264438563	943.231	939.183	-4.049	2162.001	0.000281553528606	1312.443	1308.005	-4.438
222.033	0.000044499982698	944.137	940.566	-3.570	2190.353	0.000282801367518	1320.443	1318.307	-2.136
244.406	0.000048917824561	945.182	941.458	-3.724	2208.538	0.000283577522098	1325.593	1324.103	-1.490
270.447	0.000054036147011	946.522	942.481	-4.041	2240.131	0.000284881754263	1334.573	1332.692	-1.881
293.032	0.000058452636685	947.793	944.033	-3.760	2262.848	0.000285785589649	1341.055	1340.505	-0.550
317.805	0.000063271022896	949.301	945.562	-3.739	2285.069	0.000286642655550	1347.415	1346.629	-0.786
343.415	0.000068221350033	950.984	947.720	-3.265	2313.522	0.000287701776683	1355.586	1354.231	-1.355
369.719	0.000073270929951	952.845	949.464	-3.382	2338.818	0.000288607950932	1362.875	1361.689	-1.186
393.092	0.000077726363080	954.610	952.038	-2.572	2364.031	0.000289478621626	1370.163	1368.898	-1.265
417.457	0.000082337573934	956.560	953.379	-3.181	2387.757	0.000290268853212	1377.041	1376.166	-0.874
443.392	0.000087206569064	958.759	956.346	-2.413	2414.140	0.000291115070658	1384.710	1384.134	-0.576
465.151	0.000091258686426	960.700	958.015	-2.685	2438.493	0.000291866392485	1391.809	1389.482	-2.326
493.184	0.000096433530392	963.331	960.078	-3.254	2462.794	0.000292588143421	1398.910	1396.500	-2.410
515.711	0.000100552863611	965.550	963.346	-2.204	2487.398	0.000293290967220	1406.118	1404.673	-1.445
541.511	0.000105226591981	968.205	965.572	-2.633	2515.010	0.000294046930396	1414.226	1412.021	-2.205
566.218	0.000109656444886	970.859	968.150	-2.709	2538.668	0.000294667633327	1421.191	1420.411	-0.780
594.084	0.000114597291931	973.984	971.846	-2.138	2561.908	0.000295253530062	1428.045	1425.506	-2.540
616.525	0.000118532166379	976.600	974.437	-2.163	2586.946	0.000295858859704	1435.446	1432.678	-2.768
640.390	0.000122672750671	979.478	977.709	-1.770	2611.466	0.000296426126789	1442.707	1439.409	-3.298
666.096	0.000127080367278	982.688	980.848	-1.841	2634.472	0.000296935816611	1449.533	1447.930	-1.603
686.674	0.000130569238798	985.340	983.892	-1.448	2664.740	0.000297573846661	1458.530	1457.009	-1.521
714.131	0.000135168001423	988.988	987.625	-1.363	2693.145	0.000298139716147	1466.991	1465.913	-1.078
734.065	0.000138465874302	991.715	990.735	-0.980	2713.475	0.000298525567574	1473.056	1471.688	-1.368
763.765	0.000143314660573	995.900	994.462	-1.438	2737.504	0.000298961423888	1480.234	1478.316	-1.918
790.341	0.000147586502881	999.765	998.943	-0.823	2763.498	0.000299408780058	1488.011	1486.156	-1.855
818.537	0.000152048798808	1003.990	1002.359	-1.631	2790.900	0.000299853764457	1496.222	1492.776	-3.445
838.613	0.000155181474239	1007.074	1006.107	-0.967	2818.515	0.000300275196382	1504.508	1501.544	-2.965
864.183	0.000159117277987	1011.092	1009.904	-1.188	2840.130	0.000300586546909	1511.002	1509.010	-1.993
889.644	0.000162975663823	1015.193	1015.459	0.266	2867.558	0.000300958695872	1519.252	1516.612	-2.640
916.870	0.000167033805258	1019.686	1018.333	-1.352	2891.097	0.000301258052820	1526.340	1522.475	-3.865
938.114	0.000170151328488	1023.267	1022.636	-0.631	2913.083	0.000301521298040	1532.966	1527.969	-4.997
967.871	0.000174445913874	1028.394	1028.093	-0.301	2936.480	0.000301784398540	1540.024	1537.739	-2.285
984.094	0.000176751365573	1031.243	1032.088	0.845	2963.685	0.000302068698443	1548.238	1544.497	-3.741
1014.404	0.000180991050398	1036.665	1035.925	-0.740	2985.984	0.000302284726100	1554.976	1551.710	-3.266
1043.220	0.000184939734991	1041.938	1041.995	0.058	3013.154	0.000302527708894	1563.192	1560.112	-3.081
1065.184	0.000187895435431	1046.032	1046.384	0.352	3037.280	0.000302725223191	1570.494	1566.471	-4.023
1088.895	0.000191034108912	1050.525	1050.471	-0.054	3062.143	0.000302911197517	1578.023	1575.806	-2.217
1115.015	0.000194428692814	1055.559	1055.210	-0.349	3087.867	0.000303085239153	1585.817	1582.710	-3.108
1140.098	0.000197626675935	1060.476	1060.235	-0.241	3113.355	0.000303239652968	1593.544	1587.800	-5.744
1165.295	0.000200778123168	1065.495	1065.256	-0.239	3137.870	0.000303371604994	1600.980	1597.852	-3.128
1187.085	0.000203454359188	1069.900	1070.389	0.489	3163.910	0.000303494362376	1608.881	1605.218	-3.663
1214.352	0.000206739272053	1075.492	1075.694	0.202	3187.722	0.000303591262625	1616.109	1614.170	-1.939
1238.248	0.000209559976715	1080.466	1080.502	0.035	3214.578	0.000303683339959	1624.264	1620.041	-4.222
1262.578	0.000212376180338	1085.599	1085.769	0.170	3236.351	0.000303744878128	1630.877	1627.195	-3.681
1288.093	0.000215269599056	1091.055	1092.119	1.064	3259.675	0.000303798046722	1637.962	1634.435	-3.527
1312.260	0.000217953912885	1096.290	1097.591	1.301	3288.287	0.000303845644805	1646.655	1645.422	-1.233
1337.566	0.000220706500945	1101.841	1102.887	1.046	3312.831	0.000303871344018	1654.112	1651.273	-2.839
1366.579	0.000223789487205	1108.289	1110.075	1.787	3338.804	0.000303883677531	1662.005	1660.710	-1.295
1386.806	0.000225893223524	1112.837	1113.877	1.040	3361.215	0.000303882300511	1668.815	1665.429	-3.387
1413.235	0.000228586072156	1118.842	1120.171	1.328	3387.640	0.000303866688789	1676.846	1674.863	-1.983
1434.249	0.000230682274404	1123.668	1125.078	1.410	3405.836	0.000303847313924	1682.374	1681.033	-1.341
1457.820	0.000232986663172	1129.133	1129.865	0.732	3438.279	0.000303795714058	1692.231	1690.683	-1.548
1485.368	0.000235617493175	1135.587	1136.798	1.211	3462.882	0.000303742343747	1699.705	1698.660	-1.045
1513.211	0.000238209145077	1142.184	1143.508	1.324	3488.647	0.000303673607998	1707.530	1706.745	-0.786
1539.303	0.000240576905552	1148.430	1149.417	0.986	3512.857	0.000303597318105	1714.881	1712.753	-2.128
1565.130	0.000242863363700	1154.673	1154.933	0.259	3539.715	0.000303499722545	1723.034	1720.417	-2.617
1588.644	0.000244896048707	1160.408	1160.874	0.466	3562.825	0.000303405076289	1730.047	1742.573	12.526
1612.475	0.000246909123601	1166.268	1167.062	0.794	3586.331	0.000303298910653	1737.177	1738.627	1.450
1638.883	0.000249085268628	1172.817	1173.549	0.731	3614.704	0.000303157776021	1745.781	1743.987	-1.794
1663.079	0.000251029304756	1178.868	1178.955	0.087	3639.544	0.000303022820686	1753.310	1750.378	-2.932
1689.771	0.000253119400412	1185.596	1185.425	-0.172	3664.411	0.000302877322158	1760.843	1773.884	13.041
1711.871	0.000254807248417	1191.209	1191.324	0.114	3686.858	0.000302737245925	1767.640	1767.780	0.140
1739.048	0.000256830491277	1198.162	1197.521	-0.641	3715.162	0.000302549079953	1776.206	1773.923	-2.283
1763.081	0.000258572349844	1204.355	1203.817	-0.538	3738.511	0.000302384388274	1783.269	1782.683	-0.586
1789.370	0.000260427476234	1211.177	1210.837	-0.340	3763.146	0.000302201570652	1790.715	1802.645	11.930
1814.387	0.000262144916766	1217.714	1217.784	0.070	3787.190	0.000302014366971	1797.980	1796.954	-1.026
1836.461	0.000263621994355	1223.517	1223.474	-0.043	3813.895	0.000301796539308	1806.042	1807.817	1.775
1863.985	0.000265414367520	1230.798	1231.080	0.282	3837.164	0.000301598438198	1813.062	1825.078	12.016
1888.688	0.000266976886750	1237.374	1235.614	-1.760	3863.906	0.000301361441496	1821.124	1823.494	2.370
1912.386	0.000268435572117	1243.718	1242.405	-1.313	3889.009	0.000301130114418	1828.687	1820.780	-7.907
1936.696	0.000269891489590	1250.261	1250.340	0.079	3914.736	0.000300884368276	1836.430	1833.245	-3.186
1962.993	0.000271421192709	1257.379	1255.989	-1.390	3937.224	0.000300662536404	1843.194	1860.562	17.368
1986.236	0.000272734645832	1263.703	1262.363	-1.340	3964.125	0.000300388771829	1851.279	1870.558	19.280

Table F.9b: Inhomogeneous Anisotropic Case: Forward modelling using a, b and χ estimates obtained from offset VSP times for segment 4 with receiver at 2014 m.

a = 1347.931539688680		b = 0.884981169823			χ = 0.065305746933		z = 2013.927		
offset (m)	p	computed time (ms)	observed time (ms)	residual (ms)	offset (m)	p	computed time (ms)	observed time (ms)	residual (ms)
47.917	0.000009395937084	952.259	949.852	-2.407	2031.400	0.000270438693884	1281.602	1283.866	2.263
67.679	0.000013267205690	952.483	950.437	-2.046	2057.867	0.000271831834381	1288.778	1290.939	2.160
87.531	0.000017152012800	952.785	950.647	-2.137	2078.568	0.000272891346433	1294.417	1296.333	1.916
114.917	0.000022502628735	953.328	951.544	-1.784	2109.336	0.000274418127137	1302.837	1305.118	2.281
136.226	0.000026657356263	953.851	951.374	-2.477	2133.030	0.000275555379606	1309.352	1311.261	1.908
159.548	0.000031194111175	954.526	953.025	-1.501	2156.926	0.000276669045626	1315.950	1317.697	1.746
185.804	0.000036286229626	955.412	953.865	-1.547	2181.962	0.000277800534381	1322.891	1322.426	-0.466
210.975	0.000041150443927	956.387	954.950	-1.437	2210.257	0.000279036691003	1330.769	1332.953	2.184
234.325	0.000045645336327	957.400	956.605	-0.795	2228.452	0.000279808105462	1335.853	1338.401	2.548
258.040	0.000050191679189	958.536	957.373	-1.163	2260.084	0.000281106167080	1344.725	1346.712	1.987
284.557	0.000055250510134	959.934	958.386	-1.549	2282.716	0.000282001990510	1351.097	1353.271	2.174
307.433	0.000059591892602	961.248	960.111	-1.138	2304.890	0.000282853546059	1357.360	1359.676	2.317
332.872	0.000064392884894	962.825	961.630	-1.195	2333.394	0.000283910820027	1365.437	1367.060	1.623
359.049	0.000069301582419	964.575	963.944	-0.631	2358.739	0.000284816278575	1372.644	1375.573	2.928
385.343	0.000074197692143	966.462	965.418	-1.044	2383.962	0.000285685676718	1379.839	1382.318	2.479
409.334	0.000078633266098	968.295	968.447	0.152	2407.702	0.000286475575365	1386.631	1389.120	2.488
433.705	0.000083106152550	970.266	969.921	-0.345	2434.097	0.000287322091259	1394.204	1396.500	2.296
460.001	0.000087893267459	972.514	972.838	0.324	2458.515	0.000288076000716	1401.229	1403.233	2.004
482.029	0.000091871002291	974.494	974.457	-0.038	2482.793	0.000288798331235	1408.232	1410.509	2.278
509.907	0.000096860782417	977.125	976.609	-0.516	2507.442	0.000289504394162	1415.359	1418.106	2.747
532.777	0.000100915705138	979.387	979.967	0.580	2535.041	0.000290262939964	1423.360	1425.056	1.696
558.748	0.000105477263909	982.067	981.933	-0.134	2558.701	0.000290886827482	1430.235	1432.211	1.976
583.493	0.000109779034433	984.730	985.107	0.376	2581.986	0.000291477477552	1437.015	1439.055	2.040
611.554	0.000114603221915	987.879	988.531	0.652	2607.071	0.000292088362496	1444.334	1445.480	1.146
634.129	0.000118441394268	990.509	991.086	0.576	2631.588	0.000292660417695	1451.503	1452.599	1.096
658.248	0.000122498925119	993.415	994.422	1.007	2654.653	0.000293176460279	1458.259	1459.835	1.576
684.072	0.000126792617113	996.634	997.434	0.800	2684.768	0.000293818584388	1467.097	1469.199	2.101
705.124	0.000130253353981	999.340	1000.876	1.536	2713.012	0.000294388945858	1475.404	1477.709	2.305
732.526	0.000134703616122	1002.970	1004.018	1.048	2733.279	0.000294779618038	1481.375	1482.503	1.129
752.696	0.000137939682831	1005.720	1007.432	1.713	2757.260	0.000295222170511	1488.449	1489.196	0.747
782.323	0.000142630747943	1009.876	1011.254	1.378	2783.262	0.000295678345799	1496.131	1497.292	1.160
809.041	0.000146796731247	1013.743	1015.565	1.822	2810.670	0.000296133072729	1504.242	1504.319	0.077
837.034	0.000151095070901	1017.912	1019.073	1.161	2838.309	0.000296565082731	1512.432	1512.353	-0.079
857.170	0.000154144299565	1020.986	1022.852	1.867	2859.972	0.000296885443287	1518.861	1519.220	0.359
882.753	0.000157966507412	1024.978	1026.294	1.316	2887.458	0.000297269286577	1527.026	1526.834	-0.192
908.363	0.000161734217376	1029.072	1031.885	2.813	2911.043	0.000297578908650	1534.041	1534.916	0.875
935.422	0.000165650667147	1033.501	1034.363	0.862	2933.070	0.000297851912192	1540.599	1540.726	0.127
956.725	0.000168687364062	1037.063	1038.713	1.651	2956.504	0.000298125562579	1547.582	1548.725	1.143
986.543	0.000172868301365	1042.155	1044.700	2.545	2983.778	0.000298422679435	1555.717	1555.046	-0.671
1002.868	0.000175122767489	1044.996	1049.014	4.018	3006.069	0.000298648770741	1562.371	1562.470	0.099
1033.179	0.000179243608370	1050.366	1052.495	2.128	3033.245	0.000298904493463	1570.491	1570.417	-0.075
1061.975	0.000183080185906	1055.583	1058.421	2.837	3057.374	0.000299113575333	1577.706	1578.054	0.348
1084.068	0.000185971745830	1059.660	1062.677	3.017	3082.250	0.000299311791156	1585.149	1585.655	0.506
1107.805	0.000189028244523	1064.111	1066.960	2.849	3107.982	0.000299498720033	1592.854	1593.522	0.668
1133.931	0.000192332267549	1069.093	1071.377	2.284	3133.483	0.000299666168744	1600.493	1600.080	-0.413
1159.036	0.000195447794885	1073.961	1076.518	2.557	3158.005	0.000299810846175	1607.843	1608.654	0.811
1184.402	0.000198536726859	1078.958	1081.816	2.859	3184.048	0.000299947322833	1615.653	1615.445	-0.209
1206.284	0.000201154083802	1083.331	1087.232	3.902	3207.868	0.000300056985724	1622.799	1623.756	0.957
1233.606	0.000204360506543	1088.871	1092.486	3.615	3234.734	0.000300163668205	1630.862	1630.595	-0.267
1257.536	0.000207112944396	1093.794	1096.881	3.087	3256.536	0.000300237261290	1637.407	1639.147	1.740
1281.929	0.000209865207026	1098.880	1102.535	3.655	3279.827	0.000300303301027	1644.401	1646.444	2.043
1307.463	0.000212688613685	1104.275	1108.661	4.386	3308.451	0.000300367040245	1652.998	1654.579	1.581
1331.536	0.000215296915464	1109.426	1113.833	4.407	3333.029	0.000300406772489	1660.381	1662.212	1.831
1356.935	0.000217992983649	1114.929	1119.047	4.118	3358.978	0.000300434030273	1668.176	1669.892	1.715
1386.199	0.000221028368417	1121.353	1125.490	4.137	3381.389	0.000300445682902	1674.909	1674.585	-0.324
1406.463	0.000223086303147	1125.853	1130.003	4.151	3407.830	0.000300445570665	1682.853	1683.330	0.476
1432.981	0.000225725206087	1131.803	1136.112	4.308	3426.021	0.000300436951243	1688.319	1689.103	0.784
1453.941	0.000227768126459	1136.556	1141.041	4.485	3458.467	0.000300404681350	1698.066	1699.251	1.184
1477.524	0.000230021607087	1141.954	1145.902	3.948	3483.057	0.000300366120484	1705.453	1707.174	1.722
1504.896	0.000232578083302	1148.286	1152.406	4.120	3508.829	0.000300312969659	1713.193	1714.270	1.077
1532.702	0.000235110549031	1154.788	1159.518	4.730	3533.031	0.000300251449328	1720.461	1721.476	1.015
1558.966	0.000237443680937	1160.994	1164.752	3.758	3559.898	0.000300170289723	1728.526	1730.402	1.876
1584.736	0.000239677943526	1167.142	1170.728	3.587	3583.016	0.000300089856986	1735.465	1738.836	3.371
1608.206	0.000241665849643	1172.790	1176.191	3.401	3606.516	0.000299998268209	1742.516	1744.451	1.935
1632.059	0.000243641041422	1178.578	1182.031	3.452	3634.919	0.000299874640483	1751.035	1752.517	1.481
1658.491	0.000245776963564	1185.047	1188.399	3.352	3659.735	0.000299755315040	1758.475	1760.693	2.217
1682.662	0.000247682386450	1191.010	1193.896	2.886	3684.612	0.000299625359401	1765.931	1767.779	1.848
1709.332	0.000249732473078	1197.644	1200.831	3.187	3707.066	0.000299499358928	1772.657	1774.926	2.269
1731.466	0.000251392638001	1203.190	1206.627	3.438	3735.376	0.000299329011228	1781.134	1785.556	4.423
1758.713	0.000253385682231	1210.067	1212.206	2.140	3758.721	0.000299179118426	1788.120	1792.247	4.127
1782.727	0.000255096539679	1216.172	1218.930	2.759	3783.360	0.000299011896005	1795.489	1799.150	3.661
1809.004	0.000256920386089	1222.899	1224.991	2.092	3807.424	0.000298839828008	1802.682	1805.479	2.797
1834.144	0.000258618629265	1229.380	1232.119	2.739	3834.131	0.000298638980545	1810.661	1814.840	4.179
1856.165	0.000260069272002	1235.091	1237.956	2.866	3857.404	0.000298455670986	1817.609	1823.009	5.400
1883.729	0.000261837239425	1242.284	1244.659	2.376	3884.155	0.000298235661375	1825.590	1829.612	4.021
1908.443	0.000263377870831	1248.774	1250.987	2.213	3909.264	0.000298020318231	1833.076	1837.849	4.773
1932.226	0.000264821218119	1255.055	1257.720	2.665	3935.005	0.000297790890883	1840.744	1845.303	4.558
1956.508	0.000266255873655	1261.503	1264.184	2.681	3957.499	0.000297583377504	1847.440	1852.544	5.103
1982.824	0.000267766875695	1268.530	1270.513	1.983	3984.399	0.000297326823951	1855.442	1860.716	5.274
2006.097	0.000269065714123	1274.777	1276.609	1.832					

APPENDIX G

Elliptical Rays - Upgoing and Downgoing signals

Equations used:

x corresponding to maximum of the takeoff angle (turning point) at depth Z:

$$x = \sqrt{\frac{1+2\chi}{b}(2a+bZ)Z}\,. \tag{1.38}$$

$$p(x;Z) = \frac{2x}{\sqrt{\left[x^2+(1+2\chi)Z^2\right]\left[(2a+bZ)^2(1+2\chi)+b^2x^2\right]}}, \tag{1.37}$$

Example Calculation:

For receiver at depth, Z, of 200 m and $a = 1502.014$, $b = 0.6735$, $\chi = 0.1087$.

*x = SQRT(((1+(2*0.1087))/0.6735)*(((2*1502.014)+(0.6735*200))*200))*

x = 1065.244

Substituting for x, Z, a, b, χ in equation for p above:

$p = 0.00055373$

Since ray parameter, p, is unique for a particular ray, we can use the expression below to find X corresponding to Z along the ray to $x = 1065.244$ m:

$$X = \frac{1}{pb}\left[\sqrt{1-p^2a^2(1+2\chi)} - \sqrt{1-p^2(a+bZ)^2(1+2\chi)}\right].$$

Table G.1: Elliptical Rays and Turning Points Example

Z (m)	X (m)	Z (m)	X (m)
0	0	0	1732.225
100	244.504	100	1487.721
150	423.361	150	1308.864
180	584.882	180	1147.344
190	666.968	190	1065.257
192	687.941	192	1044.284
194	711.768	194	1020.458
196	740.055	196	992.171
197	756.928	197	975.298
198	776.951	198	955.275
199	803.057	199	929.169
200	866.113	200	866.113

This is done for each ray shown in Figures 6.13a and 6.13b. The locus of points corresponding to the turning point for each set of rays is joined by the white curve in Figures 6.13a and 6.13b.